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(1) STUDIES IN INDIAN TOBACCOS

No. 3. THE INHERITANCE OF CHARACTERS IN NICOTIANA TABACUM, L.

BY

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CONTENTS

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I. INTRODUCTION.

THE chief direction in which the tobaccos of North-East India can be improved is in the introduction of superior quality. Many of the varieties at present grown give large yields and are, in consequence, very profitable, but the cured leaf produced from them is, as a rule, of very poor quality and is coarse, deficient in texture, flavour and aroma. For this reason it can be used for Indian consumption only, and, consequently, fetches a very low price. Improvements in the quality of tobacco may be obtained in three ways: (1) by the discovery of new methods of cultivation by which healthy growth is promoted and a larger yield and a better quality of leaf produced; (2) by the introduction of improved methods of curing; and (3) by the growth of superior kinds. Some of the work done at Pusa on the cultivation of tobacco has already been published.[1, 2] The investigations on curing are still in progress and it is hoped to publish shortly the results obtained. The present paper deals entirely with the third aspect of the question and is a

[1] Howard & Howard, *Memoirs of the Department of Agriculture in India*, Bot. Ser. Vol. III, No. 1, 1910.

[2] Howard, *Agricultural Journal of India*, Vol. III, 1912.

continuation of the work already published as "Studies in Indian Tobaccos, No. 2, The Types of *Nicotiana tabacum*, L.[3]" In that paper an account was given of the work done with regard to the study of varietal characters and the isolation of pure forms. The stability of the type was discussed and it was shown that there is no foundation for the belief, often expressed, that the uniformity of type in any particular kind is easily disturbed by its introduction into a new locality. If cross-pollination be prevented, varieties or types of *N. tabacum* remain as constant as those of other species of plants. This result has recently been confirmed in America by Hasselbring.[4] The methods of pollination were also studied and fifty-one pure types were isolated. These types have since been maintained in pure culture in the Botanical Area at Pusa and have bred true to type from year to year. They form the material with which the investigations, now to be described, have been carried out.

With regard to the improvement of the variety, the immediate problem at Pusa is the production of a good cigarette tobacco. The chief requirements in a cigarette tobacco for growth in Bihar are :—

1. General robustness and rapidity of growth, both in the seedling and later stages of the plant.

2. A plant of medium height with many leaves and short internodes.

3. Fairly broad leaves with small veins, so that the cigarette paper may not be damaged in the process of manufacture.

4. Yellow colour in the cured leaf.

5. Good texture in the cured product.

6. Good flavour.

The characters in which the local tobaccos are most deficient are those of texture and flavour. Several kinds have been found possessing a fair colour.

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[3] Howard & Howard, *Memoirs of the Department of Agriculture in India* (Bot. Ser., Vol. III, No. 2, 1910.

[4] Hasselbring, *Botanical Gazette*, Vol. LIII, No. 2, 1912.

Many attempts have been made in the past to introduce into India the best varieties of cigarette tobacco from America, but the results have been disappointing. This is due to several causes, some of which are avoidable. In the first case, insufficient care was taken to prevent cross-pollination, and the introduced varieties, by crossing with the indigenous crop, deteriorated. In the second place, many of the varieties were unsuited to Indian conditions by their habit of growth. The practice in America of topping at a high level has favoured the growth of tall kinds, which carry their best leaves well above the ground, making low or medium topping impossible. This is a serious disadvantage in the plains of India, where high winds frequently occur and damage tall varieties or those with thin leaves. Another defect was noticed in all the American varieties tried at Pusa, namely, the slow growth of the seedlings. Although sown at the same time as the indigenous varieties, transplanting could only be carried out a fortnight or ten days later in the case of the American kinds, and there was a corresponding lag all through the growth period. This is a very great disadvantage in Bihar, where one of the secrets of success in tobacco-growing lies in the maximum utilization of the growth period from October to mid December. During this period, the temperature is still high enough for rapid growth to take place and the soil still contains plenty of moisture. After the middle of December, when the temperature falls, growth is much less rapid, and the plant should then be nearing maturity and be ready to be cured about the end of January, in order to avoid the dry hot winds which do so much damage during the latter process. A crop, which through lack of food materials or through the lateness of the variety makes little growth during October and November, remains more or less stationery during December and January and begins to grow again as the temperature rises in February. Such plants seldom attain any great size, and very frequently do not ripen evenly. The difficulty in curing the product during the period of the hot west winds is

an additional disadvantage. Owing to lateness and want of robustness, the yield of the American varieties is far below that of the coarse local kinds and this would be fatal to their successful introduction.

The chances of improving the quality of Indian tobacco by the introduction of a new variety from America are therefore not great. It will be necessary to build up, by hybridization, new kinds of tobacco, suited to Indian conditions of growth, which possess in addition the qualities necessary to obtain a better price. Fortunately, the introduced American kinds, although they lose their colour by the native method of curing, nevertheless maintain their good texture and flavour, the chief points in which the Indian tobaccos are deficient. Thus by combining these desirable qualities with those of an indigenous tobacco, which is robust and possesses a suitable habit of growth, a very great improvement might be effected. Unfortunately, however, although tobacco is grown over so large a portion of the world, very little work has been done on the hybridization of this crop and little is known as to the inheritance of the various characters which are of economic importance. As in hybridization lies the greatest chance of producing a permanent improvement in the tobacco grown in the plains, and as it is possible to obtain at Pusa all the facilities necessary for such an enquiry, it was decided to take up the question and to make a thorough investigation of inheritance in this crop, beginning with those morphological characters which are of economic importance, namely, those concerning the habit of the plant and the leaf. The subject has proved to be far more complicated than was at first supposed, and the present paper must be considered to be a preliminary one only. It will probably take some years to obtain a complete knowledge of the subject.

Besides its economic importance, there is another point of great interest involved in the genetics of *N. tabacum.* Most of the characters are concerned with the size of organs, and the

inheritance of these can only be determined by quantitative means. The importance of a thorough study of the inheritance of characters, which can be accurately measured, instead of depending on observation alone, has been pointed out by many writers.[1, 2] Until recently, most of the investigations on inheritance, undertaken from the Mendelian standpoint, have dealt with characters of a qualitative nature, that is, they have dealt with characters which depend on the presence or absence of a particular attribute, such as colour, hairs or awns. Forms in which these attributes are absent occur and can be used as analysers, and the observations are restricted to a detection of the presence of the character involved. By a judicious use of the analysers and a careful analysis of the progeny, it is generally possible by observation alone to determine the principles underlying the inheritance. Characters connected with the size of organs present more difficulty. In the first place, no absence of the character is possible and no analysers exist. Take, for instance, the height of a plant or the length of a leaf, a plant without height or a leaf without length is inconceivable. Thus in such characters we are dealing with difference in degree only; observation is insufficient and measurement must be employed. In the second place, such characters are generally very sensitive to changes in environment and show marked fluctuating variability. Such fluctuating variability may be inherent in the plant, or may be directly due to the influence of the environment on the character under consideration, or indirectly to the effect of the environment on the general vigour of the plant. Should the changes due to fluctuating variability be greater or almost as great as the differences in the characters under investigation, they may obscure or entirely mask the effects of inheritance. East[3] was one of the first to point out that so-called

[1] Tammes, *Recueil des Travaux Botaniques Néerlandais*, Vol. VIII, 1912

[2] Nilsson-Ehle, *Kreuzungsuntersuchungen an Hafer und Weizen*, Lund, 1909, *Kreuzungsuntersuchungen* II, Lund, 1911.

[3] East, *The American Naturalist*, Vol. XLIV, 1910

continuous variation was capable of a Mendelian interpretation. The whole subject of the inheritance of characters with fluctuating variability has been very ably dealt with recently by both Tammes[1] and Nilsson-Ehle.[2] The latter was the first to show that characters, which to the eye appear similar, may in reality be due to different genes which are inherited independently. The red colour of the pericarp of some wheats is composed of three factors, each of which will independently produce a red colour, although less intense in tone than that due to the combination. Recent work everywhere endorses the complicated nature of most characters and has resulted in a large increase in the number of factors recognised, while at the same time the visible effect due to each factor appears smaller. In the paper quoted above, Nilsson-Ehle discusses fully the question of fluctuating variability and variation in general, and points out that fluctuating variability may only exist as an effect of environmental influence. If the number of factors n is large, the number of homozygotic combinations possible will be much larger, *i.e.*, 2^1 and the differences between these combinations will be smaller than the differences between the factors themselves. If the heterozygotic forms are intermediate in value between the homozygotic combinations, we may obtain a continuous series in the F_2 generation and as the combinations of middle values occur most frequently, the form of the curve, obtained in a graphic representation of the F_3 generation, will resemble that of an ordinary frequency curve. The heterozygotic combinations, which occur at different points on this curve, will in the F_3 and succeeding generations give a progeny which varies within much smaller limits than those of the F_2. Assuming a large number of small factors, this is sufficient to explain all variation which is not induced by environment. A plant which exhibits small fluctuations in any one character may be heterozygotic as regards that character and it should be

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[1] Tammes, *l.c.*

[2] Nilsson-Ehle, *l.c.*

theoretically possible to extract different types which breed true from it. In practice, however, errors of measurement and observation or environmental influence may be too great for such types and their heterozygotes to be distinguished. From these considerations as well as the experimental evidence of his own researches, Nilsson-Ehle concludes that there is no inherent difference in the mode of inheritance between quantitative and qualitative characters and that all variations may be placed in two groups :—

1. Variations which are inherited.

2. Variations which are not inherited and which are probably entirely due to changes in the environment.

It is obvious that the larger the number of factors in which the parents differ and the greater the effect of environment, the more difficult it becomes to separate the factors or to determine the exact mode of inheritance. If we consider the case of two parents, which differ from one another in three factors, there will be in the F_2 generation eight homozygotic combinations and nineteen heterozygotic, which, in general, will lie between the homozygotic forms. Thus we obtain a series containing twenty-seven stages between the two parent forms. If the original difference between the parents is not very large, these forms will lie very close to one another. If, in addition, environmental differences supervene, the limits of variation of one form will very soon overlap those of the next or even of several others, in fact, in many cases, the limits of the two parents themselves overlap.

Taking these facts into consideration, it is not surprising that up to the present in no case has the inheritance of the size of an organ been entirely elucidated and the various factors determined. All that has been possible has been to show that segregation undoubtedly occurs and that the facts are in accordance with the Mendelian interpretation and with the existence of many factors, all capable of being inherited independently. In the investigations described in this paper it has been possible

not only to show segregation in many of the characters, but also to isolate forms resembling the parents as well as some new constant forms differing from either parent.

The most thorough examination of the inheritance of characters connected with the size of organs are the investigations of Tammes[1] on the length and breadth of the seed and the length and breadth of the petal in *Linum*. The size of the seed was found to be practically unaffected by the environment and therefore formed very suitable material for such work. The limits of variation and the co-efficient of variability were carefully determined for each parent. It was found that while the F_1 generation was intermediate between the parents, the second generation could not be separated into groups, but formed a continuous series, and that, in many cases, no individuals could be found which resembled the parents. In the F_3 generation no individuals breeding true or resembling either parent could be found but the limits of variation were smaller than in the F_2 and differed in each case, the combined variation covering the limit of variation of the F_2 generation. These results point to the existence of several factors with segregation. The various intermediate heterozygotic forms would naturally contain fewer heterozygotes than the F_1 generation, and would therefore vary within smaller limits.

East and Hayes,[2] in 1911, published similar results on size characters in maize, such as height of the plant, length of cobs, weight and size of seeds, but in most cases the investigations were not taken beyond the second generation.

Three investigations on the characters connected with the size of the organs in tobacco have been published, but in no case have the investigations been carried beyond the second generation. Lock,[3] in 1909, published a preliminary note of some species crosses in the genus *Nicotiana*, the characters considered

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1 Tammes, *l.c.*

2 East and Hayes, *Bulletin* 167, *Connecticut Agricultural Experiment Station*, 1911.

3 Lock, *Annals Royal Botanic Gardens, Peradeniya*, Vol. IV, 1909.

being the colour, shape and size of the corolla. As the investigation is complicated by the fact that species crosses were employed with consequent sterility and as it is admittedly only a preliminary account with very few data, it need not be further considered here.

A much more important paper dealing with *N. tabacum* only was published by Hayes[1] in 1912. The correlation and inheritance of various characters such as the height of the plant, number of leaves, average area of the leaves, average width and average length of the leaves, were investigated in hybrids between various pure types of American tobacco. Full details are given of the measurements, but in no case have the cultures been carried beyond the second generation. It was found that the variability in the F_1 generation and the parents was similar but much greater in the F_2 generation. These results are most easily explained by the presence of a large number of small factors with segregation. As regards the correlation between these characters, the co-efficient in all cases was found to be less than +. 5, except in the case of the length and width of the leaf, where a distinct plus correlation was found. The conclusions, as regards the individual characters, will be considered in more detail in the separate sections dealing with each character in Chapter IV, but it may be remarked here that although the results are undoubtedly valuable, many of the measurements are taken in what appears to be a somewhat arbitrary manner. For example, the number of leaves counted is not the total number of leaves borne on the main stem of the plant, but the number of leaves which occur between the fifth leaf from the ground and the last leaf on a topped plant, this representing the total number of leaves generally harvested. Such numbers have an economic but no physiological meaning. Similarly the height is measured to the last leaf counted, not to the end of the main axis of the plant. As the habit of growth of the American types used is very similar, discrepancies due

[1] Hayes, *Bulletin* 171, *Connecticut Agricultural Experiment Station*, 1912.

to this method of measurement are not so great as they would be in the case of many Indian tobaccos (see Plates I and II). Nevertheless these arbitrarily chosen points cannot give the expression of the true physiological activity of the plant as regards height and number of leaves.

A third paper on the inheritance of quantitative characters in *Nicotiana* is that published by Goodspeed.[1] In the first part of these investigations a comparison is made between the weight of the seeds obtained by hybridization and the plants produced from these seeds. *N. tabacum* var. *macrophylla*, a variety with heavy seed, and *N. tabacum* var. *virginica*, a variety with light seed, were employed as parents. The seeds of the F_1 generation were divided into three groups, heavy, light and medium, and it is stated that in the plants raised from the heavy seeds the greater number of individuals resembled var. *macrophylla*, while in the culture raised from the light seeds the greater number resembled var. *virginica*. The three classes of seeds showed a difference in germinating power which was largely influenced by time. The conclusion is therefore drawn that very variable results may be obtained in the F_2 generation which are due merely to the differential germinating power of the various heterozygotic and homozygotic combinations. The experimental data on which these conclusions are based can, however, only be regarded as most unsatisfactory. In the first place, considering the number of characters and the probably infinitely larger number of factors involved in the difference between two *varieties* of tobacco, it would be practically impossible to divide the F_2 generation into three well-defined groups and any such division which might be attempted would have no significance. In the second place the original division of the hybrid seed into three groups is open to question for the same reason. The difference between these seeds probably depends on several factors, and to these must be added environmental effects due to nutrition and pollination. Very little meaning can be attached

[1] Goodspeed, *University of California, Publications in Botany*, Vol. V, No. 2, 1912.

to results in which so many approximations have to be made. In the second part of the paper, an investigation into the inheritance of the length of the corolla in three varieties of *N. acuminata* is described and the author states that, although this character shows very small fluctuations in the parents, the variation in the F_1 is very great and covers the whole difference between the two parents. The details of the F_2 generation have not yet been published.

The only other investigations on hybridization in the genus *Nicotiana*, which are known to me, are those by Jensen[1] and Lodewijks.[2] Hybridization experiments were started by Jensen in 1906 and the crosses investigated in most detail were those between Peru, a variety with a petiolate leaf, and White Burley, Peru and Maryland smoking. The intermediate nature of the F_1 and the great complexity of the F_2 generation, with a total absence of the parent forms was emphasized. The most interesting point is the appearance of new characters in the offspring which were not present in either parent.

[1] Jensen, *Jaarboek van het Department van Landbouw in Neederlandsh-Indie*, 1907 1908, 1909, 1910, 1911.

[2] Lodewijks, *Zeitschrift für induktive Abstammungs und Vererbungslehre*, Bd. V, 1911.

II. THE METHODS OF RAISING THE EXPERIMENTAL PLANTS.

THE methods employed at Pusa in raising the experimental plants have already been fully described[1] in a previous paper, and it will only be necessary briefly to recapitulate them. In experimental work on tobacco, the two most important points are: (1) to raise the seedlings without contamination, and (2) to eliminate, as far as possible, all differences due to environmental influences.

The seeds of the tobacco are so small that they are very easily carried from one culture to another by wind, rain, earthworms, or by the hands of the workmen. The seed is brown and indistinguishable from the soil, and retains its vitality, even under adverse conditions, for several years. The practice adopted at Pusa is to raise the seedlings in large shallow boxes, and every precaution is taken to collect the earth and leaf-mould from places where contamination by stray tobacco seed is impossible. The boxes are made up about six weeks before sowing and kept moist, so as to cause any stray seeds to germinate. So far (1908 to 1912) no tobacco seedlings have been found in the boxes prior to sowing. The boxes are sown, one at a time, and the sower has to wash his hands before sowing another box. After sowing each box it is immediately removed into the shade till the seedlings appear. They are then enclosed in a wire netting fence to keep off animals, and are placed so far apart that the earth from one box cannot be splashed on to an adjacent one by the sudden tropical storms which sometimes occur at this season. Precautions are taken during the process of thinning to prevent admixture and this operation is only

[1] Howard and Howard, *l.c.*

carried out under personal supervision. The boys who do the work have to wash their hands after finishing each box, as otherwise a few ungerminated seeds might be carried to other cultures. After transplanting, the soil in the boxes is thrown away and the boxes washed. These precautions have proved successful and in no case has any mixture of the cultures been discovered.

The elimination or rather the reduction of the differences due to environmental influence is much more difficult. There is perhaps no plant which is so sensitive to changes in soil, climate and external conditions generally as the tobacco. The shortness of the growth period, the large amount of material in the form of leaves and stem formed in a short time are probably the reasons why any check or stimulus has so great an effect. Moreover, the tobacco plant appears to have an infinite capacity to adapt itself to conditions, the same pure type giving rise to plants 1½ feet or 8 to 10 feet high according to the cultivation. Even in very adverse circumstances the plant goes through its complete cycle and forms seed. Apart from such extremes, a very small difference in cultivation is sufficient to induce a very marked change and to raise a field of plants uniform enough for accurate measurement is not easy. Nevertheless, in all plant-breeding experiments, the absolute necessity of normal and well-grown plants cannot be emphasized too strongly. The differences induced in tobacco plants apart from size are almost incredible. The general effect of unfavourable environment on *N. tabacum* is to wipe out all differences and to make the plants appear uniform. The differences between the various types in leaf shape and leaf surface, which are small, almost disappear in under-developed plants. Unless the plants are well grown, it would be very easy to be misled in observations on such characters as the undulations of the leaf surface. The numbers would probably show far too great a proportion of flat leaves.

Owing to the large amount of experimental work carried on in the Botanical Area at Pusa, special care has been taken to

render the land as uniform as possible. The plots are all small, carefully levelled and are well drained and cultivated, and for most crops they present an ideal experimental basis. In the present investigations, a certain amount of trouble has been experienced even on these experimental plots. Slight local unevenness of the ground due to ploughing, a difference in the subsoil drainage, and the proximity of a hedge have all had an effect. It is needless to say that all cultures which could possibly have been affected have been rejected. The cultures which have to be directly compared are grown on the same plot in lines and the two parent types are grown at both ends of the plot, and also in the centre. In this way, should there be any slight change in the conditions from one side of the plot to the other, it would be indicated by the range in variation of the parent forms. The impossibility of obtaining a large piece of land with uniform drainage and soil must always limit the number of cultures grown, even if the amount of work entailed did not do so. One other important point must be mentioned, namely, the time of transplanting. If many plants die after the first transplanting and have to be reset, the replaced plants, even though only a week later in planting, always remain behind the earlier ones. By adopting a system of furrow irrigation, and using great care in removing the seedlings from the nursery boxes, the loss in transplanting in the experimental cultures has been reduced to a minimum. Only one replacement is carried out two or three days after the first transplanting. Should others die, their places remain blank, but the system of transplanting adopted has proved so successful that the number of such blanks is very small indeed ; the number of deaths before the first replacement is generally not more than one per cent.

The methods of crossing and raising the self-pollinated seed are those in ordinary use, and need not be specially mentioned. Full details have been given in a former paper.[1] The only point

[1] Howard and Howard, *l.c.*

which calls for comment is the limitation imposed on the number of possible observations by the labour connected with the raising of all the seed under bag. Many of the types will not set good seed unless they are selfed, and the time taken in carrying out all the details connected with this and the bagging of a large number of plants is considerable. The raising of the seed and the observations on the leaves have to be carried out during the same period, between the formation of the first flowers and the partial destruction of the leaves by death or the ordinary chances of breakage. This in Bihar is a very short period, and even by devoting the whole day to the work the number of observations which can be carried out in the time falls far short of those desired.

III. THE OCCURRENCE OF PARTHENOGENESIS.

The question of parthenogenesis in *N. tabacum* was taken up in consequence of a paper published in the *Mendel Journal.*[1] In this communication the author stated that she had been able to obtain parthenogenetic seed with the greatest ease in the case of *N. sylvestris, N. tabacum, N. suavolens, N. sandera,* and hybrids from these. In some cases only the anthers were removed, but in others both anthers and stigma, while the ordinary precautions of sterilizing the instruments and enclosing the flowers in wax-paper bags seem to have been scrupulously observed. Success did not attend all the experiments, but "parthenogenesis was discovered in ten species, varieties and hybrids of *Nicotiana* on chosing the right period for trial, *i.e.*, when the plant is beginning to go off its fullest bloom. In the tabacums success was unfailing." East[2] also mentions the possible production of apogamous seed. "In crossing species of the genus *Nicotiana* I have had plants develop from seed that have apparently been formed apogamously, that is, formed from an immature egg-cell without fertilization. It is evident that this is induced by the extraordinary irritation of foreign pollen."

Experiments were undertaken both in 1910 and 1911 to determine whether, under the conditions obtaining in Pusa, *N. tabacum* will set seed without pollination. It had already been observed that castrated flowers prepared for hybridization, which owing to pressure of work or other reasons had not been pollinated, invariably dropped without setting any seed. In order to obtain more definite information on this point, a large

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[1] Haig Thomas, *The Mendel Journal,* No. 1, 1909.
[2] East, *The Popular Science Monthly,* 1910.

number of flowers on two individuals in nearly all the fifty-one types of Indian tobaccos, and also in some F_1 hybrids, were castrated. About fifty to one hundred flowers were prepared on each plant under every possible condition. In some the anthers were removed, in others, both anthers and stigma. The plants used included types which self-fertilize with great ease and those which will set hardly any seed unless selfed, as it was thought that the latter would be the most likely to produce parthenogenetic seed. Plants were chosen at all periods of their growth—when in full seed formation, when full of capsules and going off their bloom, and when very nearly over. In most cases the plants were heavily pruned, all capsules, flowers and buds other than the castrated ones being removed (such heavy pruning ordinarily induces rapid seed formation), others were lightly pruned. The same methods were adopted in 1911, but here the number of kinds employed was smaller, only those used as parents in the hybridization experiments were tested again, namely, Types 9, 51, 16, 35, 23 and 38. The castrated flowers were enclosed in parchment bags and these were taken off at frequent intervals in order that any newly-formed buds might be removed. In the earlier experiments the bags were not applied after the corollas had withered, but in the later experiments bags with perforations were placed over some of the branches. A great difference was found between the capsules formed from the castrated flowers and those formed by ordinary pollination. In the latter case the capsule swells quickly and remains firmly attached to the plant. No difficulty is experienced in removing or replacing bags, and the peduncle would have to be broken before the capsule could be removed. This is always the case, whether the flower be self- or cross-pollinated. The capsules of the castrated flowers, on the other hand, although they also became swollen at first and simulated the fertilized ones, were very easily detached from the plant. It was exceedingly difficult to remove the bags, which finally had to be cut away carefully. The capsules thus exposed to the air were

easily blown or knocked off. For this reason half of them were enclosed in large well-perforated bags as a protection. Some of the capsules obtained a fair size, but were not so large as the normal ones. On examination they were, however, found to be quite empty, the ovules not having developed. On only three plants did seed set in all the thousands of flowers which had been castrated, and the total number of capsules was five. In 1910, on a plant of Type 9, about one hundred flowers were castrated and one fully formed capsule was found, the seed of which germinated and produced plants similar to Type 9. In 1911, again, on a plant of Type 9, one capsule containing seed was found in about one hundred castrated flowers. In this type the stamens are so much shorter than the style, that if enclosed in a bag the flowers normally set no seed and the majority of the capsules drop. It has always been found necessary to self this type in order to obtain sufficient pure seed to maintain the culture. If the seeds in these two capsules were due to apogamy, this method of seed production must be the exception and not the rule. It is of course possible that the two capsules were due to errors in castration. The other three capsules were found on one plant of another type, but by an accident these were not examined. They were large, well-formed capsules, apparently containing seed, but unfortunately were destroyed before this fact had been definitely ascertained.

Considering the great number of flowers examined and the fact that every stimulus to apogamous seed formation had been given to the plants by pruning and capsule removal, the results obtained are exceedingly small, even if we assume that all five capsules contained parthenogenetically formed seed.

In addition, in all the first generations (nine in number) which have been raised at Pusa during the last five years, each culture containing about one hundred plants, no individuals resembling the mother plant have been detected. The cultures have been absolutely uniform and the reciprocals identical. I

have no hesitation in saying that under the conditions obtaining at Pusa in ordinary hybridization work, parthenogenesis in *N. tabacum* is negligible.

It is interesting to note that in the details given by Jensen[1] of an experiment undertaken to test the possibility of wind pollination in *N. tabacum*, no mention is made of the formation of apogamous seed. Four plants bearing 119 castrated flowers were covered by a net and so placed that the prevailing wind must bring pollen to them. In none of the flowers did any seed set. The uniformity of the F_1 generation and the identity of the reciprocals has also been mentioned by Jensen and by Hayes.[2]

[1] Jensen, *l.c.*
[2] Hayes, *l.c.*

IV. THE EXPERIMENTAL RESULTS.

THE material used in these investigations formed part of the types, isolated in 1909, which have since been maintained in pure culture. Since at the time these experiments were begun nothing was known concerning the correlation or interdependence of the various characters in tobacco, it was decided to make a preliminary survey of the inheritance of practically all the characters which deal with the stem and leaves. This was done partly with the object of ascertaining how far the inheritance of the individual characters could be studied independently, and partly to determine the most suitable methods of investigation. It is hoped to follow this preliminary account by a more comprehensive study of the more important characters. The characters which have been considered in the present investigation are (1) time of flowering, (2) height of stem, (3) arrangement of the leaves on the stem, (4) length of the decurrent portion of the lamina, (5) venation of the leaf, (6) leaf-shape, (7) undulation of the surface and margin of the leaf.

In all, five crosses have been made, Type 9 × Type 51, Type 16 × Type 35, Type 23 × Type 38, Type 2 × Type 3, and Type 2 × Type 51. The first, that between Type 9 and Type 51, has been carried to the F_4 generation, those between Type 16 and Type 35 and Type 23 and Type 38 to the F_3 generation. Only the F_1 generation has so far been raised of the other two. It will be seen from the photographs of Type 9 and Type 51 (Plates I and II), and from the full description of the types reprinted as an appendix to this paper (p. 108), that these two forms differ in almost every character, from height of plant to the mode of pollination and colour of the corolla.

PLATE I.

TYPE IX.

TYPE II

PLATE II

PLATE

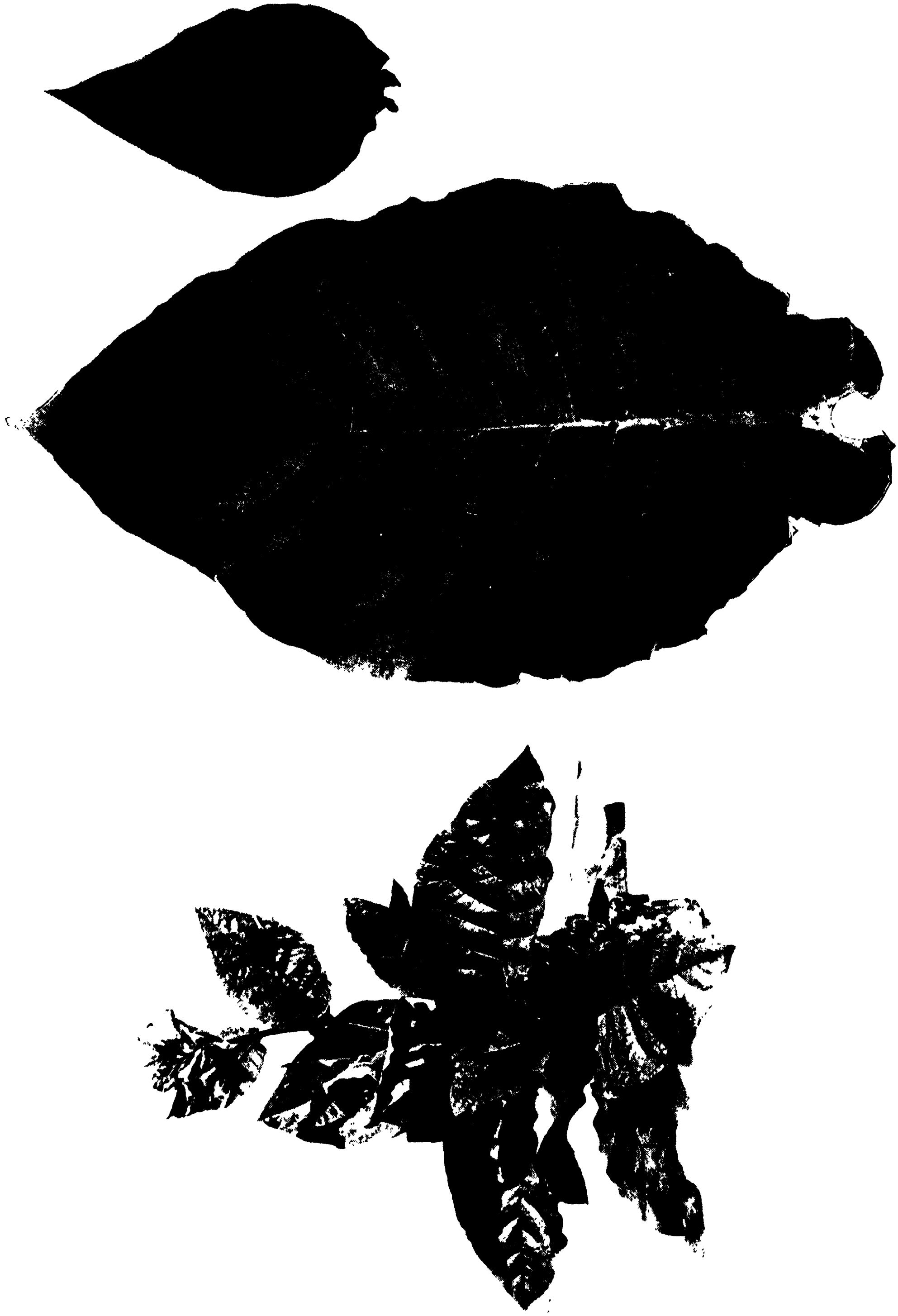
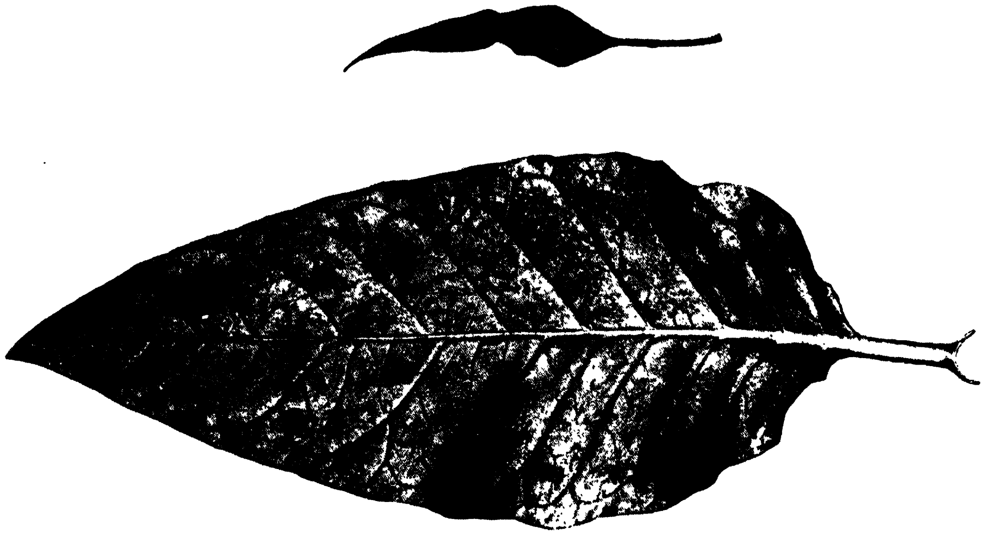


PLATE V.

TYPE XXIII.

TYPE XXXVIII.

PLATE VII



TYPE II

F_1 $T_{23} \times T_{38}$.

F_1 $T_{16} \times T_{35}$.

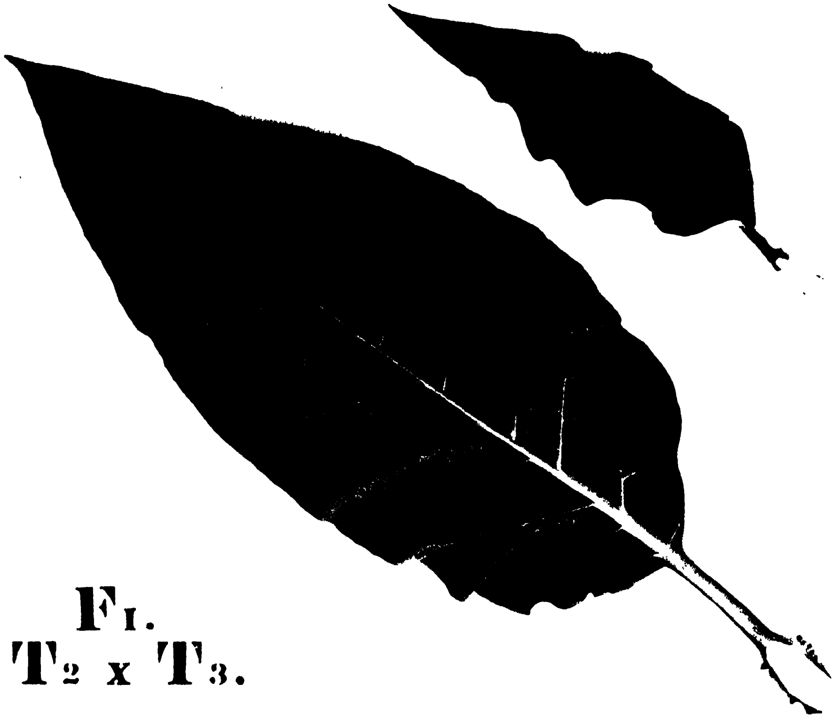
F_1 $T_9 \times T_{51}$.

FIRST GENERATION OF CROSSES IN N. TABACUM.

F1
T9 x T51

F1
T23 x T38

FIRST GENERATION IN N. TABACUM.

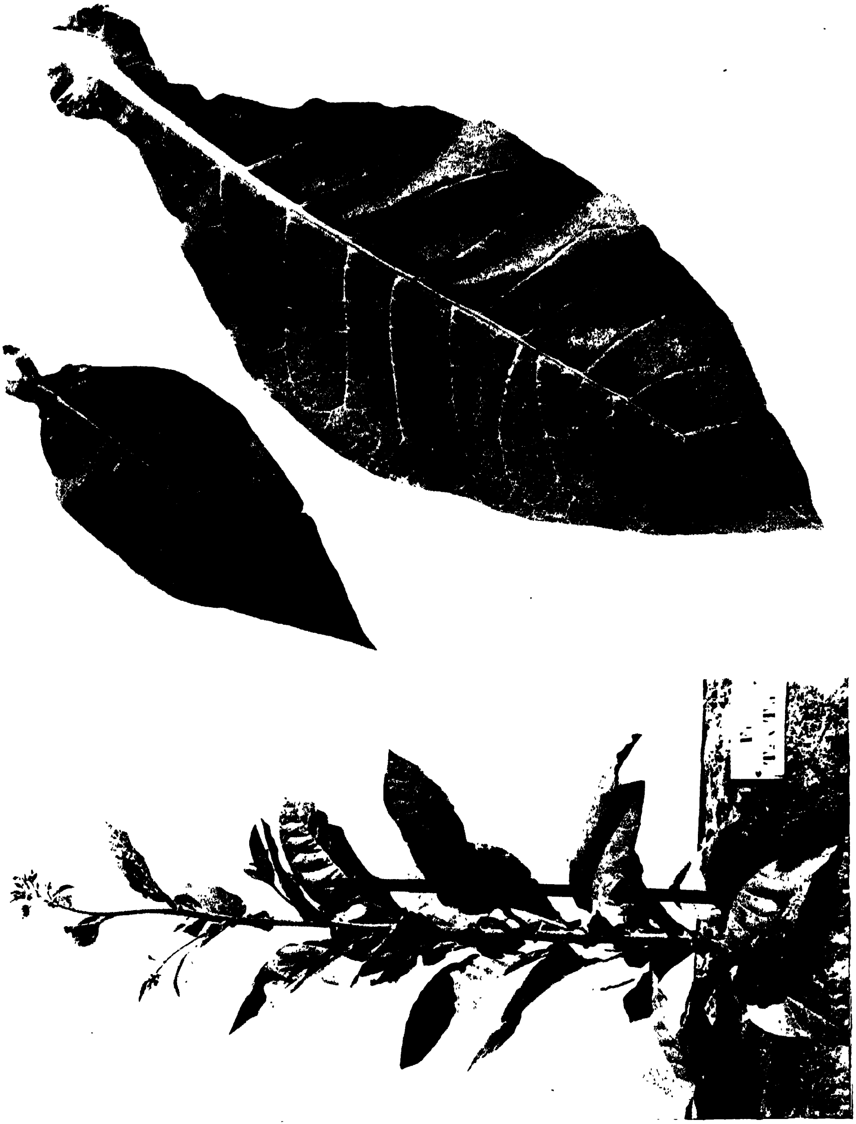


F_1.
T_2 x T_3.

F_1
T_{16} x T_{35}

FIRST GENERATION IN N. TABACUM.

PLATE XII.



FIRST GENERATION. TYPE 2 × TYPE 51.

In Type 16 and Type 35 (Plates III and IV) we have two forms which, while not very different in height or habit, nevertheless differ markedly in the number of leaves. The main object of the cross between these two forms was an investigation of the leaf shape. Type 35 has the broadest and Type 16 one of the narrowest leaves in all the fifty-one types, while the length is nearly the same in both. The cross between Type 23 and Type 38 (Plates V and VI) was primarily made on account of the difference in the number of leaves on plants almost equal in height. The average number of leaves in Type 23 is nineteen or twenty, in Type 38 about thirty-five. Types 2 and 3 (Plates VII and VIII) are both petiolate forms, but the petioles are alate to a varying degree. In the cross Type 2 × Type 51 (Plates VII and II) a form with a petiolate leaf was crossed with a leaf with a broad base. The most striking result of these hybridizations was the formation of new forms quite outside the range of either parent. For instance, in the F_2 generation of Type 16 × Type 35, dwarf plants, much shorter than Type 35, and tall forms, almost equal in height to Type 16 and Type 35 combined, were found, and some of these have bred true in the F_3 generation. Similarly, in the cross Type 23 × Type 38, petiolate forms breeding true were produced, although both parents have sessile leaves. Reciprocal crosses were always made and grown side by side both in the F_1 and F_2 generations. In no case could any differences between the crosses and the reciprocals be detected. The F_1 was intermediate between the parents in almost all the characters (Plates IX, X, XI, XII).

Details regarding the manner in which the actual measurements were taken will be given in the section on the individual characters, but a few words of explanation may be given here on the number of plants used in the experiments. As explained in a previous chapter (p. 38), the area of uniform land available, the labour involved in the raising of the seedlings and the transplanting, but more especially the shortness of the period during which measurements can be made, limits the amount

which can be accomplished. The descriptions of the various types of tobacco already published show that the different forms of *N. tabacum* can be arranged as regards each character in a series, each member differing very slightly from the next (see also Tables VII, XII, XX). This would lead one to expect a large number of factors in connection with each character, and in the F_2 generation a long series of intermediates, with the very rare occurrence of the parent forms. The chances of directly analysing such an F_2 generation are small. A very large number of individuals would have to be raised in the F_2 generation to obtain any indication of the percentage of plants resembling the parents, and, since the range of variation in the parents due to external influences is considerable, it would be quite impossible to recognise such forms with certainty. This being the case, there seems very little point in undertaking the labour of raising many thousands of plants in the F_2 generation. The plan adopted has been to grow not less than 1,000 plants in the F_2 generation in order to obtain a fair idea of the extent of variation by eye, and then measure as many as possible of these, generally 300 to 600. Self-pollinated seed from plants, which together cover more or less completely the range of variation, was taken and these cultures raised in the F_3 generation. In the F_3 cultures about 200 plants were grown from each parent, and 100 to 200 measured. No choice was exercised in connection with the plants measured. Two or three complete lines of the culture were taken. The limits of variation in the F_3 generation are much smaller. In some cases the cultures apparently bred true in some one character. A similar procedure was adopted in the F_4 generation.

The number of plants used is small and the investigation cannot pretend to be statistic, but the larger the number of plants the smaller must be the number of cultures. The number employed is sufficient to determine whether the culture is uniform or is splitting within narrow limits. The object in adopting this procedure is to obtain as many as possible

of the intermediate forms pure, as the extraction of the various intermediate homozygotic forms appears to be the easiest and most conclusive way of determining the principles underlying the inheritance. The range of variation of the parents was determined each year for each character. In 1911, very few of the parent plants were sufficiently well developed to be measured. The cultures were transplanted into a field which had been green-manured. Owing to the exceptionally heavy and prolonged monsoon of that year, the soil conditions were not favourable to the proper utilization of the green manure, and the plants only developed well in the high-lying portions of the field. The F_2 generation of Type 9 × Type 51 and the crosses of this back on to the parents were normally developed, but most of the parent cultures and the F_1 generation of the other four crosses were very uneven. This explains why the measurements given for the F_1 generation are of a later date than those of the F_2. In all these cases the crosses had to be re-made and the work repeated. Similarly, in 1913, as there were a large number of cultures to be grown, some of the lines of the parents were pushed as near the hedge as appeared safe. Unfortunately, the influence of the hedge had been under-estimated, and although the last line was twenty feet from the hedge, the plants developed very slowly, and were so stunted that they had to be rejected. These accidents make the number of measurements carried out on the parents smaller than is desirable.

I. TIME OF FLOWERING.

The date of opening of the first flower on each plant was taken as the criterion of this character. All the plants were numbered and the cultures were examined daily at approximately the same time in the morning. The climate of India is very well adapted for all such investigations, as the days are almost invariably sunny, and irregularities due to the periods of cloud and low temperature consequently negligible. The results for the three crosses, Type 9 × Type 51, Type 16 × Type 35 and

Type 23 × Type 38, are given in Tables I, II, III. In order to shorten the tables the data are given in three-day periods. The date of flowering of the parents under the same conditions was determined each year.

The most interesting results are those for the cross, Type 9 × Type 51. The parents vary greatly in time of flowering. The flowering period of the first generation is intermediate between the two, but nearer that of Type 9, the earlier parent. The F_2 generation shows a wide range, but the flowering periods of the parents is unfortunately not available for this year, 1911. It may, however, be noted that the flowering period of the F_2 covered two months, a period greater than that covered by both

. Seven cultures were grown in
tinct difference can be seen in the
al cultures. Three, namely 738, 736
ength to both parents combined,
less resemble Type 51. Cultures
groups, namely 738 and 694, were
nd six plants of the former and
the F_3. It will be seen that the
again segregated. Two, 738-15
ly the period of the two parents.
r than the early parent, and the
es. The culture 694 has, on the

TABLE I.

Date of Flowering. Type 9 × Type 51.

	Date of Flowering of Parent.	January										February.									March.						Total No. of Plants.
		4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-2F.	3-5	6-8	9-11	12-14	15-17	18-20	21-23	24-26	27-1M.	2-4	5-7	8-10	11-13	14-16	17-19	
F_2 Type 9 × Type 51 (1911)		—	—	—		—	1	1	1	11	25	30	55	76	74	132	86	64	50	33	15	17	12	1	4	2	690
	1911																										
Type 9 (1912)		—	5	11	22	27	23	6	1	—	—		—	—	—	—	—	—		—		—	—		—	—	95
Type 51 (1912)				—	—	—	14	30	25	8	9		—	1	—	—	—	—	—	—		—	—	—		—	87
F_1 Type 9 × Type 51 (1912)		—	—	2	11	26	21	14	3	2	—								—	—	—	—	—	—	—	—	79
F_3 Type 9 × Type 51 (1912)																											
737	Feb. 8th	—		—	3	16	32	34	15	14	11	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	126
738	Feb. 8th	1	12	11	26	25	31	26	8	7	2	2	—	1	—	—	—		—	—	—	—	—	—	—	—	152
736	Feb. 10th	1	—	1	5	10	24	35	19	23	9	5	5	—	—	—	—	—	—		—		—		—	—	137
740	Feb. 13th	—			—	—	25	54	20	21	6	3	5	—	1	1		—	—	—	—	—	—	—	—	—	136
132	Feb. 13th	—	—	—	—	—	7	28	32	22	18	7	1	2	—	—		—	—	—	—		—	—	—	—	117
694	Feb. 15th	—	—	—	—	—	5	14	12	26	21	7	7	4	3	1	—	—	—	—	—	—	—	—	—		100
167	Feb. 16th	—	1	—	2	2	11	24	14	9	14	6	9	3	4	1	—	—	—	—	—		—	—			100
	1912																										
Type 9 (1913)		—	—		—	—	7	13	8	2	3	2	2	—	—		—	—	—	—	—	—		—	—	—	37
Type 51 (1913)		—	—		—	—	—	—	—	—	—	3	8	5	9	3	3	1	1	3	—	1	—	—	—	—	37
F_4 Type 9 × Type 51 (1913)																											
738-15	Jan. 8th	—	—	—	1	6	12	19	32	30	26	18	16	12	2	1	3	—		—	—	—	—	—	—	—	178
738-19	Jan. 11th	—	—		5	19	36	39	38	28	8	4	—	—	—	—	—	—	—			—	—	—	—	—	177
738-81	Jan. 15th	—	—	1	6	34	57	50	19	6	4	3	—	—	—	—	—		—		—	—	—	—	—	—	180
738-58	Jan. 16th	—	—	—	—	—	7	29	23	25	21	35	17	11	5	2	—	—	—	—	—	—	—	—	—	—	175
738-96	Jan. 24th	—	—	—	—	1	—	10	10	18	15	26	24	26	23	7	7	6	1	2	—		—	—	—	—	176
738-76	Feb. 2nd		—	—	—	—		2	5	15	18	43	31	24	19	8	7	5	2	—	—	—	—	—			179
694-1	Jan. 25th	—	—		—	—	—	—	7	17	23	49	40	17	13	7	3	—	2	1	—	—	—	—	—	—	179
694-103	Jan. 30th	—	—	—	—	—	—	—	—	—	—	2	6	10	18	12	18	18	20	9	18	5	2	—	—	—	138
694-10	Feb. 3rd	—	—	—		—	—	—	—	—	—	3	8	16	15	19	20	30	31	12	11	4	4	—	—		173
694-23	Feb. 4th	—	—	—	—	—	—	—	—	—	—	—	—	1	17	18	24	33	33	21	24	14	4	4	—	1	194
694-38		—	—	—	—	—	—	—	—	—	—	—	7	3	12	10	11	21	20	28	22	21	11	6	2		174

Table II.

Type 16 × Type 35.

Date of Flowering.

	Date of Flowering of Parent.	January. 4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-2F	February. 3-5	6-8	9-11	12-14	15-17	18-20	21-23	24-26	27-1M.	2-4	March. 5-7	8-10	11-13	14-16	17-19	Total No. of Plants.
Type 16 (1913)											1	7	10	10	6	1	1										36
Type 35 (1913)								1	2	1	2	4	8	9	5	2	2	1									37
F_1 Type 16 x Type 35 (1913)								1	1	11	14	14	18	7	2	2	2	1									73
Type 16 (1912)					3	16	20	24	8	11	13	2	1														98
Type 35 (1912)					1	10	18	19	20	15	12	1	3		1												100
F_2 Type 16 x Type 35 (1912)				6	14	59	75	89	48	34	20	14	1	1	1												362
	1912																										
Type 16 (1913)											1	7	10	10	6	1	1										36
Type 35 (1913)								1	2	1	2	4	8	9	5	2	2	1									37
F_3 Type 16 x Type 35 (1913)																											
15	Jan. 11th									2	6	19	28	39	30	5	6	3	4	1		1					144
8	Jan. 15th										1	1	14	21	32	21	27	10	10	5	3						145
163	Jan. 15th									3	5	29	47	22	14	14	2	3	1	1		1					142
27	Jan. 19th						4	20	15	41	30	32	16	9	8	1	3										179
190	Jan. 19th							1	3	23	39	42	29	12	11	9	7	3									179
202	Jan. 21st							5	10	22	18	38	40	27	16	4											180
251	Jan. 21st									8	18	23	41	25	17	8	2	2		1							145
35	Jan. 23rd											1	17	26	40	28	16	7	4	2	1						142
9	Jan. 24th									3	3	19	31	25	13	12	1	3		1							114
231	Jan. 24th									2	8	22	30	19	27	9	8	2	3								130
112	Jan. 27th									2	3	9	21	32	32	17	13	6	5	4	1						145
200	Jan. 31st											3	10	8	19	26	25	23	21	1	3	2					144

Table III.

Type 23 × Type 38.

Date of Flowering.

	Date of Flowering of Parent.	January. 4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-2F	February. 3-5	6-8	9-11	12-14	15-17	18-20	21-23	24-26	27-1M.	2-4	March. 5-7	8-10	11-13	14-16	17-19	Total No. of Plants.
Type 23 (1913) ..								10	2	9	3	2		1													27
Type 38 (1913) ..											1	3	7	7	4	3	1										26
F_1 Type 23 x Type 38 (1913)								10	3	12	9	14	10	13	3	2											76
Type 23 (1912) ..				1		1	24	27	16	6	10	3	1														89
Type 38 (1912) ..							1	1	7	25	26	11	8		1												80
F_2 Type 23 x Type 38 (1912)			1		4	6	62	89	77	49	39	13	4														344
	1912																										
Type 23 (1913) ..								10	2	9	3	2	—	1													27
Type 38 (1913) ..											1	3	7	7	4	3	1										26
F_3 Typo 23 x Type 38 (1913)																											
104	Jan. 24th					1	3	24	18	34	31	21	10	6	1	2		1									152
155	Jan. 24th							5	21	42	24	29	19	11	4	1	1	2									159
213	Jan 21st							9	11	29	29	31	20	18	4	2	3										156
159	Jan. 23rd							9	17	28	35	31	20	9	4	2	2										157
111	Jan. 25th							9	10	32	31	36	20	7	3	5	2										155
204	Feb. 2nd							1	3	13	28	30	26	13	5	4	5	1		1							130
6	Jan. 23rd							3	—	10	12	23	27	25	14	9	4	3	1								131
117	Jan. 31st							2	3	16	25	30	46	25	20	11	3	2	2								185
9	Jan. 26th										1	9	16	23	20	21	11	13	7	3	—	1					125

other hand, given rise only to late plants. The difference between the cultures derived from 738 and 694 was most marked in the plot. There is a good deal of difference between the individual cultures of 694. No. 694-1 has a maximum flowering period between the two parents, while 23 and 38 are much later than Type 51, the late parent. It is impossible to say whether a culture is pure as regards its time of flowering until it has been proved impossible to produce from it by selection cultures differing in this character, but 738-19 and 738-81 may possibly prove constant, as may also some of the cultures of 694.

If we consider the F_4 cultures as a whole, we find a very distinct separation as regards the flowering period. In addition, while one culture has been isolated, which is slightly earlier than the early parent, there are several which are decidedly later than Type 51, the late parent. The range of the earliest flowering culture does not overlap that of the latest.

Tables II and III show the same general results for other crosses, but the separation between the cultures is not so great, as the flowering period of the parents is not very different in either case. The extremes in the F_3 are represented in the cross Type 16 and Type 35 (Table II) by cultures 27 and 200, and in cross Type 23 × Type 38 by cultures 104 and 9. In all three the two parents in successive years bear a similar relation to one another.

2. HEIGHT.

The height was measured from the point where the roots begin to the apex of the stem, which in *N. tabacum* ends in a capsule. Three or four flowering branches arise round this point and help to define it, but there is no difficulty in seeing either the capsule or its scar at any period in the life of the mature plant. In order to count the lower leaves, the plants were uprooted and the determinations of the height and the number of leaves were made simultaneously. The height was measured

PLATE XIII.

SECOND GENERATION. TYPE 16 × TYPE 35.

to the nearest centimetre, but in order to reduce the number of data and to remove accidental inequalities, the heights are given in classes differing by five centimetres in Tables IV, V, and VI.

Height is one of the few characters which in the F_1 generation is not strictly intermediate between the two parents, and the results in the five crosses were not the same. The F_1 hybrid between Type 9 (a dwarf form) and Type 51 (a very tall form) was nearly as tall as the taller parent. The actual mean measurements were, in 1910, Type 9—68 cm., F_1—140 cm., Type 51—165 cm., and in 1912, Type 9—79.9 cm., F_1—158.0 cm. and Type 51—195.4 cm. In the cross Type 16 × Type 35, in which the respective heights were, Type 16—106.3 cm., F_1—93.7 cm. and Type 35—86.6 cm., the height is intermediate. In the other three crosses the F_1 was taller than either parent. This increase in height was slight in the case of Type 23 × Type 38, but very marked in the other two crosses. The actual measurements were Type 2, average height, 155 cm., Type 3, average height, 152 cm., F_1 200 cm., Type 51, 178 cm., F_1 Type 2 × Type 51, 195 cm. It has been suggested, in the case of maize,[1] where the F_1 is also not strictly intermediate, that this is due to the increased vigour of the hybrid plants. This may be the explanation here, but it is difficult to see why this increase should be so much more marked in some cases than in others, unless this increase in vigour be correlated with the number of factors in which the parents differ.

The F_2 generation in the cross Type 9 × Type 51 presented no striking features. A continuous series was formed within the limits of the parents.

The F_2 generation of the cross between Type 16 and Type 35 was absolutely different. These two parents do not differ very greatly in height, the average height of Type 35 in 1912 was 94.1 cm., with a range of 60 to

[1] East, *l.c.*

110 cm., that of Type 16, 125.2 cm., with a range of 110 to 140 cm. The heights in the F_2 generation varied from 48 cm. to 215 cm., and the plot presented an extraordinary mixture of dwarf and tall forms. Plate XIII shows some of the F_2 forms, photographed at an equal distance from the camera. A large number of plants were self-pollinated and twelve cultures from these were raised in the F_3 generation. These cultures could be easily divided by eye into three groups, those in which all the plants were short, that is, no taller than either parent, Nos. 251,

TABLE

Height.

		Height of Parent.	Centimetres. 40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
Type 9	1910		—	—	—	—	—	Mean 68		—	—	—	—	—	—	—	—	—	—
Type 51	1910		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
F_1 Type 9 × Type 51	1910		—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
F_2 Type 9 × Type 51	1911			—	12	13	14	16	25	41	42	41	56	49	57	40	41	32	48
Type 51 × F_1 Type 9 × Type 51	1911		—	—	—		—		—		3	2	1	2	3	4	4	8	8
Type 9	1912		—		—	—	—	1	2	13	8	13	2	2	—	—	—	—	—
Type 51	1912			—	—		—		—	—		—		—	—	—	—	—	—
F_1 Type 9 × Type 51	1912		—	—	—	—	—	—	—	—		—		—	—	—	—	—	—
F_3 Type 9 × Type 51																			
738—1912		82	—		—	2	3	14	10	21	17	12	22	17	5	9	9	1	1
737—1912		114		—	—	—		—	2	2	6	2	7	11	3	6	9	14	15
694—1912		137	—		—	—	—		—	—	—	1	1	2	1	2	3	9	6
167—1912		145	—	—	—	—	—	—	—	—	—		—	—	1	2	2	—	4
740—1912		157	—		—	—	—		—		—	—		—	—	—	—	—	
736—1912		160		—	—		—	—		—	—	—	—	—		—	—	—	2
132—1912		?	—	—	—		—		—	—		—	—	—	—	—	1	—	—
Type 9	1913		—	1	3	7	7	7	2	2		—	—	—			—	—	—
Type 51	1913		—		—		—	—	—	—		—	—	—		—	—	—	—
F_4 Type 9 × Type 51																			
738—96—1913		81	2	5	13	29	56	39	23	4	—	1		—	—	—	—	—	—
738—76—1913		86	—		—	1	2	5	16	25	30	15	21	11	14	9	9	2	1
738—15—1913		86	5	6	17	33	25	38	24	7	9	4	3	1	—	—	—	—	—
738—19—1913		?	—	1	2	2	15	20	12	10	14	8	4	2	—	—	—	—	—
738—81—1913		91	—		1	1	3	4	13	28	28	23	24	28	14	4	2	—	—
738—58—1913		123	—	—		—	—			3	9	10	22	35	28	29	16	11	3
694—1—1913		?	—	—		—		—	—		2	8	.	17	19	18	22	32	21
694—103—1913		?	—	—	—			—		—	—	2	3	6	3	8	7	8	18
694—10—1913		?	—		—		—	—	—		—	—	—	—	3	3	4	16	22
694—23—1913		?	—	—	—		—		—	—	—	—		—	—	—	—	5	2

Mean height Type 9 1912, 79·9 cm.
Type 51 1912, 195·4 cm.
F_1 Type 9 × Type 51 1912, 158 cm.
F_3 culture 740—1912, 195·2 cm.

200, 142 and 190; those in which all the plants were tall, cultures 35, 15, 9, 163; and cultures in which both short and tall plants occurred, Nos. 202, 27, 231 and 8. In the last four cultures it was quite easy to separate the tall and short plants by eye, and although neither class was uniform, the short and tall plants together did not form a perfect series. Among the cultures with short plants, two have apparently bred true, No. 251 and No. 190. In 1912, No. 251, with a height of 48 cm., was the shortest plant in the F_2 generation; in 1913, this gave

V.

Type 9 × Type 51.

Centimetres.																									Total
5	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	No. of Plants.
								Mean 165																
		Mean 140																						
27	19	23	15	17	7	5	3		2															648
6	9	8	8	10	5	10	5	3	5	2		1												107
																								41
							1		1	1	3	7	6	4	5	4		3	2	1	1			39
1		2	1	2	9	5	6	1	3	1	5	2												38
																								143
6	7	5	9	6	4	2	4	6	1	1														128
9	7	7	14	8	6	3	2		2															93
6	3	5	11	10	8	12	10	7	7		3	2	1											94
						1	3	1	5	13	13	18	16	9	17	5	9	7	9	2	7		1	136
2	3	2	6	3	5	7	4	6	10	9	8	10	12	13	5	7	5	3	1	2	1			126
	1	6	4	5	11	7	11	8	10	10	9	8	7	3	4	6	1	1		1	1			115
																								29
									1	4	5	3	6	6	4	4								33
																								172
																								164
																								172
																								90
																								173
1																								168
5	5	4																						170
6	8	11	7	5	1	6																		109
29	26	35	11	11	4	1																		165
3	7	12	15	17	20	28	21	14	18	8	5	1	1											177

Mean height Type 9 1913, 57·5 cm.
Type 51 1913, 188·3 cm.
F_4 culture 738–96 1913, 60·1 cm.
F_4 culture 738–58–1913, 98·7 cm.

TABLE

Height.

	Height of Parent.	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	11
		Centimetres.															
Type 35 1911											Mean 87						
Type 16 1911																	
F_1 Type 16 × Type 35 1911																	
Type 35 1912							1	1			1	8	5	9	13	7	
Type 16 1912																	
F_2 Type 35 × Type 16 1912				1		3	2	7	6	20	14	19	23	36	25	29	25
Type 35 1913										2	4	13	10	4			
Type 16 1913														1	5	14	8
F_1 Type 16 × Type 35 1913											2	9	21	24	5	5	1
F_3 Type 16 × Type 35																	
251—1913	48	1	10	35	49	26	18	5									
200—1913	73			1		2	3	11	16	28	19	36	18	6	3	2	
142—1913	81					4	9	11	28	33	31	11	15	2			
202—1913	83					6	6	18	27	26	20	14	14	8			[illegible]
27—1913	88		1	9	12	12	21	17	15	19	15	13	6	3	3	3	2
231—1913	90		1	2	5	[illegible]	7	10	12	16	12	16	10	6	1	2	
8—1913	116						1			3	8	13	21	20	18	11	13
190—1913	131								1	1		6	15	28	58	25	27
35—1913	180																1
9—1913	182																
163—1913	195																
15—1913	204														1	1	

Mean height Type 16 1912, 125·2 cm.
Type 35 1912, 94·1 cm.

TABLE

Height.

	Parent. Cm.	65	70	75	80	85	90	95	100	105	110	115
		Centimetres.										
Type 23 1911												
Type 38 1911												
F_1 Type 23 × Type 38 1911												
Type 23 1912									1	2	5	4
Type 38 1912										1	4	5
F_2 Type 23 × Type 38 1912				1	8	18	12	30	21	38	30	28
Type 23 1913											2	4
Type 38 1913												
F_1 Type 23 × Type 38 1913												
F_3 Type 23 × Type 38 213—1913	117			1		5	6	3	9	13	15	13
117—1913	102·5	1	1	1	1	10	11	11	15	17	22	21
155—1913	108			2	1	6	7	12	10	20	16	14
111—1913	128					1	2	1	5	7	11	14
159—1913	139							1	2	2	7	11
104—1913	151											
9—1913	155											
6—1913	166·5											
204—1913						1	5	4	12	18	20	16

Mean height Type 23—1912, 119·1 cm.
Type 38—1912, 133·0 cm.

Type 16 × Type 35.

	Centimetres.																							Total
115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	No. of Plants.
Mean	121	Mean	135																					
																								45
7	3	7	17	7	1																			43
7	14	7	8	4	7	4	4	9	8	10	8	8	8	6	9	6	4	1	1	1				356
																								33
4																								32
																								67
																								144
																								145
																								144
	3	3	11	5	6	6	2	4	3	1	1													186
	6	5	6	5	3	2	1	1																186
2		6	6	3	7	5	4	4	2	1														146
2	3	2	1		6	3	2	9	4	3	1	1												148
12	4	4																						181
			2	4	9	6	8	14	17	18	19	17	10	6	5	2	1				1			140
	1	2	1	1	6	7	10	14	19	16	13	4	5	2	1									102
	3	4	1	2	10	10	14	20	23	19	18	6	5	2	1									138
5	1	1	2	5	6	11	8	11	10	11	15	16	11	6	8	5	7			1				142

Mean height Type 16 1913, 106·3 cm.
Type 35 1913, 86·6 cm.
F_1 Type 16 Type 35 1913, 93·7 cm.
F_2 culture 251—1913, 50·8 cm.
F_3 culture 190—1913, 102·1 cm.

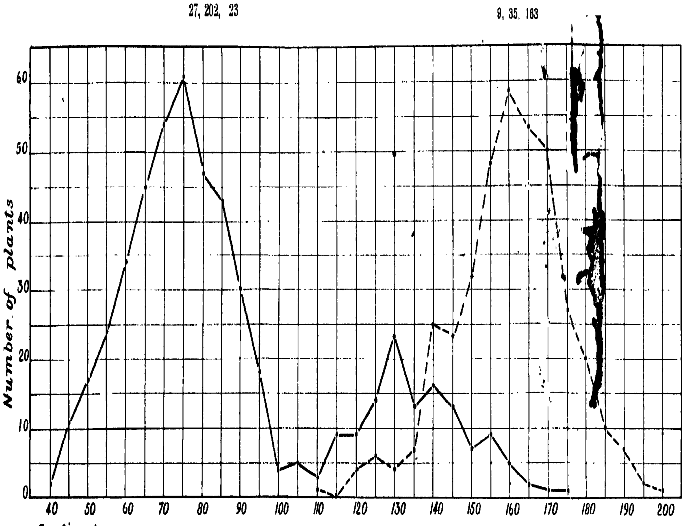
Type 23 × Type 38.

	Centimetres.																	Total
120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	No. of Plants.
	Mean	133																
	Mean	130																
	Mean	132																
4	5	1	1	2														25
3	3	4	1	3	5	3	2		1									35
23	19	21	18	18	10	12	5	8	3	2	4	1	1					331
8	3	4	1	1														23
	1	—	4	6	2	5	1											19
	—	—		5	5	12	7	5	7	3	2	1						47
12	11	9	12	9	6	4	1	3	1		1							134
17	14	10	9	7		2	3		1					1				175
9	14	9	8	4	6	6	2	1	1	2								150
7	12	18	11	12	18	8	7	6	1	2		1						144
17	12	17	18	17	11	9	9	6	5	2	1	3						150
1	—	1	2	6	5	8	21	20	23	22	15	13	6	6	2	1	1	153
—	1	—	2	5	8	11	16	15	17	13	16	11	6	3				124
		2	6	3	5	9	11	10	15	13	9	5	10	6	6	3	5	118
19	11	3	5	2	1													117

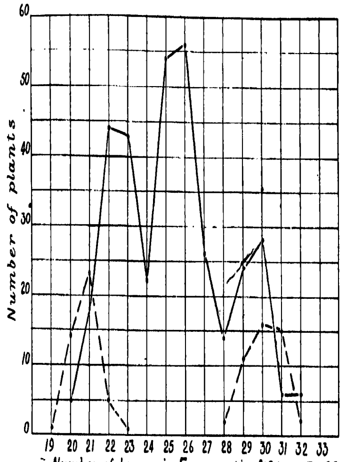
Mean height Type 23—1913, 122·9 cm.
Type 38—1913, 142·3 cm.
F_1 Type 23 × Type 38—1913, 154·6 cm.

rise to a culture which appeared absolutely uniform in the field. The average height of the culture was 50.8 cm., much less than that of Type 35, and the limits of variation (35 to 65 cm.) do not overlap those of Type 35. The individual heights of the plants, if graphically represented, give a curve which resembles greatly the ordinary frequency curve of a uniform culture. This fact, combined with the appearance of the culture in the field and the small range of its variation, makes it probable that 251 represents a culture constant as regards height. We have thus the formation in the F_3 of a new form much shorter than either parent. The factor or combination of factors which is represented by this average height of about 50 cm. may be present in both parents, or only partly in both, but the fact that this combination has been isolated shows that the height of Type 16 cannot be composed of small factors superposed on those possessed by Type 35. Even if we suppose that the combination of factors denoted by a height of 50 cm. is common to both parents, all the factors which go to form the excess of height over 50 cm. in Type 35 and Type 16 must be different. This gives the explanation of the very tall plants in the F_2 and F_3 generations. Since so large a proportion of the height in the parents is due to different gametes, the combined effect of such gametes would be additive.

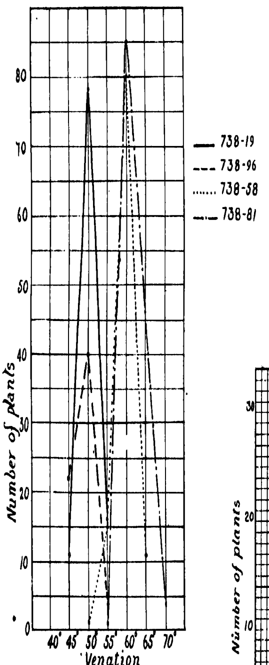
There is no definite evidence as to the number of the factors involved, but from the appearance of some of the F_3 cultures they would seem to be few in number. Culture 190 is also probably uniform and a reproduction of Type 16, the mean height in the one case being 102.1 cm., in the other 106.3 cm. The range of variation is greater, but this may be due to the larger number of plants measured. From their appearance in the field and the curves given by their height it is probable that the cultures 142 and 200 are not uniform, but represent heterozygotes between two nearly allied combinations. After 251, the most interesting culture is 202. Here we have a distinct break between the tall and the short plants,



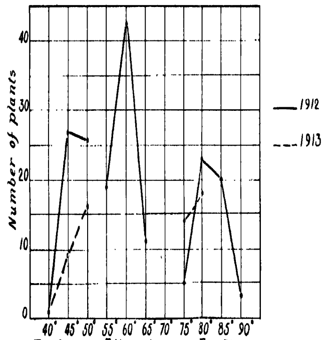
Heights in F_3 Type 35 X Type 16



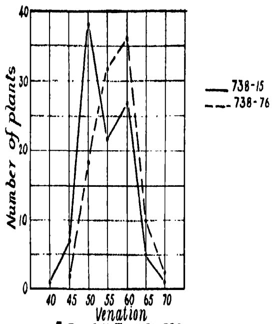
Number of leaves in F_2 generation & Parents, Type 35 x Type 16



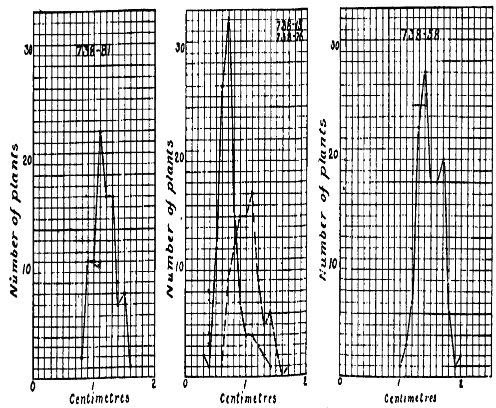
F_4 Type 9 X Type 51-738



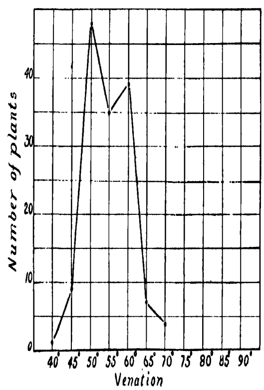
Type 9 F_1 Venation Type 51



F_4 Type 9 X Type 51-738



Length of the decurrent portion of the lamina F_4 Type 9 x Type 51-738.



F_3 Type 9 x Type 51-738

and the tall plants form exactly one quarter of the whole. The large range of variation in the tall forms indicates that the ratio is not a simple 3 : 1. Cultures 27 and 231 show a similar result, an accumulation below 95 cm., a total break, or very few plants about 100 and a rise beyond this. These three cultures were derived from three F_2 plants of very similar height, 83, 88 and 90 cm. The curve formed by combining these cultures is shown in Plate XIV. Culture 8 is very similar to these three cultures, but the curve appears to be shifted to a higher value. The cultures 9, 35 and 163 are all similar and seem to point to at least two homozygotic combinations at about 120 and 170 to 180 cms., with possible intermediates. The combined curves from these three cultures is given in Plate XIV; the individual cultures all agree with this. A large number of plants have been self-pollinated and the F_4 should give sufficient uniform cultures to identify all the factors. The values obtained in some of the cultures seem somewhat high for a rudimentary height of 50 cm. common to both parents. The fact that in all the cultures grown in the F_2 and F_3 nothing shorter than 50 cm. has been thrown out would point to nothing smaller than this combination existing in either; yet if this factor or combination be common to both, the mean of the highest combination possible can only be (85—50) + (106—50) + 50 cm. The limits of the tallest homozygotic combination should also throw light on another interesting point. Since every plant must have height, it is reasonable to suppose that all types possess a common factor which represents the smallest height which the tobacco plant can possess. This, either by the superposition of numerous small factors or by combination with various independent factors, gives the height of the different plants. The first supposition of small superposed factors is entirely disproved by the cross (Type 16 × Type 35), in which plants have been produced almost equivalent to the combined height of both parents, showing that the constituents of the height of both parents must be almost all different. Should a

homozygotic combination be produced equal or greater than the sum of both parents, this may be explained by the greater vigour produced by hybridization or by supposing a different rudimentary height in different plants, or that the factor giving height exists in all plants but has no definite external expression. Both these hypotheses, however, would introduce many difficulties.

The results in the cross Type 9 × Type 51 (Table IV) need not be considered in such detail. The range of variation in the F_2 was not greater than the range of the parents combined. In the F_3 generation, the eight cultures showed a great difference in the range of variation, but only one appeared to be uniform. Culture 740 (Plate XV) resembled the parent, Type 51, in every respect, both in the limits of variation and in the average height. The average height in the case of 740 was 195.2 cm., and the limits of variation 155 to 240 cm.; in the case of Type 51 the average was 195.4 cm. and the range 160 to 230 cm. Both cultures were grown side by side in the field and there was no difference in their appearance. A form resembling one of the parents was therefore isolated in the F_3. The difference in the range of variation in the F_2 and F_3 generations distinctly indicates a segregation, as well as the probable occurrence of homozygotic combinations representing heights intermediate between the two parents. One such was isolated in the F_4 generation (738-58), as well as a culture resembling Type 9 (738-96). From their appearance in the field, their range of variation and the form of the curve obtained by graphic representation, both these cultures appear to be homozygotic. The average value of the height in 738-96 is 60.1 cm., that of 738-58 is 98.7 cm. The height of culture 738-96 is probably the same as that of Type 9 (average height 57.5 cm.); the other forms a *novum*. The remaining cultures of 738 are not uniform and contain these two combinations with possibly an intermediate. The F_4 cultures of 694 are also not homogeneous, but their limits of variation are very different to

THIRD GENERATION. TYPE 9 × TYPE 51. No. 740.

those of the cultures obtained from 738 and indicate the occurrence of a number of intermediates. This would point to factors of small value. From the fact that no plants shorter than Type 9 have been found in all the generations, it would appear as if Type 51 must contain the factors which go to build up the height of Type 9.

In the cross between Type 23 and Type 38 the matter is complicated by the fact that the F_1 is taller than either parent. The F_2 again shows a greater range of variation than the combined range of the parents and the large number of plants shorter than Type 23, the shortest parent, is especially noticeable. In the F_3 cultures the limits of variation are very different, cf. cultures 204 and 6. The occurrence of plants shorter than Type 23 is again marked. No cultures uniform in height have yet been obtained from this cross. Distinct segregation is, however, apparent, and there are indications that Type 23 and Type 38 contain certain factors in common which give a height somewhere about 80-85 cm. and that the other factors involved in the height of both parents are different, giving rise by combination to plants taller than either parent.

3. THE NUMBER OF LEAVES PER PLANT.

This character is somewhat unsatisfactory on account of the amount of variation in each pure type, in proportion to the total variation possible between the types. The smallest number of leaves found in any kind is nineteen, the greatest thirty-four. Table VII shows the approximate number of leaves in each type—the average number of leaves in ten plants. Want of time prevented the measurement of a larger number of plants. It will be seen that every possible number of leaves present and all occur with approximately equal frequency.

The total number of leaves on the main stem was measured in the following manner. The plants were uprooted, the large roots cut off short, and the base of the plant well washed. It was then possible to count all the leaf scars as well as the living

TABLE VII.

Average Number of Leaves in the Types of *N. tabacum*.

	No. of Leaves		No. of Leaves.		No. of Leaves.
Type 41	19·5	Type 17	23	Type 37	26
,, 40	20	,, 41	23	,, 1	26
,, 23	20	,, 15	23	,, 10	27
,, 12	20	,, 21	24	,, 39	27
,, 43	20·5	,, 27	24	,, 8	27
,, 34	20·5	,, 15	24	,, 50	28
,, 35	21	,, 7	24	,, 46	28
,, 36	21	,, 11	24	,, 51	29
,, 47	22	,, 26	25	,, 4	29
,, 48	22	,, 49	25	,, 16	30
,, 13	22	,, 25	25·5	,, 31	31
,, 6	22	,, 30	26	,, 5	33
,, 12	22	,, 2	26	,, 38	34

leaves. Enumeration at the base, where the scars are close together, is facilitated by marking the point of commencement with a knife, and each subsequent scar by sticking into it the point of a lead pencil. Care is necessary not to mistake contractions in the main root for leaf scars, but with a little practice this can be done fairly easily, except in the case of a few types. The determination of the last leaf on the axis is more difficult. In many types of tobacco, the leaves at the top of the stem are carried up the branches they subtend and therefore do not appear to be on the main stem. In such cases, however, there is generally a faint line running from the leaf down to the main stem. The method of enumeration adopted in these investigations has an advantage over previous methods used in that it represents the true physiological activity of the plant and not an arbitrary number.

As regards the effect of environment on the number of leaves, no special investigations have been undertaken, but the fact that the average value of this character and the range of variation in the parent forms is practically constant in different years, would indicate that changes in a normal environment have little effect. This agrees with the conclusion of Hayes that the number of leaves per plant was little affected, unless the

conditions were so unfavourable as to greatly stunt or dwarf the growth of the plant. It is possible, however, that the length of the growth period may have some influence. As stated on page 38, in 1913 a portion of the parent cultures were grown too close to a hedge and developed very slowly in consequence. These plants, when they did attain maturity, all had an abnormally large number of leaves. For instance, Type 51, instead of possessing the normal number of twenty-seven to thirty-one leaves, had thirty-one to thirty-five leaves, and a similar increase was noticeable in Type 35. Moreover, in 1913, a late season, the average values of all the parents was about one leaf greater than in 1912. Again, in 1911, another late season, the average value of Type 51 agrees with that of 1913. In the absence of further evidence this can only be put forward tentatively. The ordinary fluctuations of season have no appreciable effect. The number of leaves per plant apart from these abnormal individuals appears to be a very definite inheritable character.

Much attention has been paid, in the course of these investigations, to the question of a correlation between the the number of leaves and the height of the plant ; but it is quite clear that each can be inherited independently of the other. Some of the shortest plants have the largest number of leaves. Take for instance culture 251 (Tables V and IX) in the F_3 generation of Type 16 Type 35. This culture is uniform as regards height (av. 50.7 cm.) and uniform as regards leaves (av. 30), that is, it has a greater average number of leaves than Type 51, of which the mean height is 195.5 cm. Culture 190 of the same cross has an average height of 102.1 cm. and the average number of leaves is thirty. Such instances might be multiplied indefinitely. Cases also occur in which the culture is uniform as regards height, but not as regards number of leaves per plant (for example, 740 in the F_3 generation of Type 9 × Type 51) and vice versa. The fact that, while the height varies greatly with the season, the number of leaves remains

Table VIII.

Number of Leaves per Plant. Type 9 × Type 51.

	No. of Leaves in Parent.	Number of Leaves. 17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total No. of Plants.
Type 9 1911		—	—	1	4	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17
Type 9 1912		—	—	—	2	12	12	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35
Type 9 1913		—	—	1	14	32	16	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	66
Type 51 1911		—	—	—	—	—	—	—	—	—	—	1	1	5	1	2	—	—	—	—	—	—	—	—	—	10
Type 51 1912		—	—	—	—	—	—	—	—	—	—	6	13	9	4	1	—	—	—	—	—	—	—	—	—	33
Type 51 1913		—	—	—	—	—	—	—	—	—	—	—	5	14	5	4	1	—	1	—	—	—	—	—	—	30
F_1 Type 9 × Type 51 1912		—	—	—	—	—	—	5	16	13	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	37
F_2 Type 9 × Type 51 1911		—	3	6	11	26	17	35	41	68	58	62	67	43	52	34	40	25	23	13	5	5	4	8	1	647
Type 51 × F_1 Type 9 × Type 51 1911		—	—	—	1	—	4	5	7	12	16	18	19	24	6	4	4	—	—	—	—	—	—	—	—	120
F_3 Type 9 × Type 51																										
738—1912	20	3	7	9	18	27	27	22	21	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	135
737—1912	23	—	—	—	—	2	6	13	25	20	23	17	16	3	1	—	—	—	—	—	—	—	—	—	—	126
736—1912	25	—	—	—	—	—	2	12	16	20	36	16	16	8	2	2	—	—	—	—	—	—	—	—	—	130
745—1912	25	—	—	—	—	3	6	18	21	18	32	30	18	11	4	—	1	—	—	—	—	—	—	—	—	162
694—1912	26	—	—	—	3	6	18	10	10	10	12	9	4	5	4	1	—	—	—	—	—	—	—	—	—	92
167—1912	27	—	—	1	3	5	6	15	5	15	7	9	4	7	6	3	1	1	1	—	—	2	—	—	—	91
740—1912	31	—	—	—	—	—	—	—	—	6	9	19	27	23	23	9	8	4	—	—	—	—	—	—	—	128
132—1912	?	—	—	—	—	—	—	—	—	1	3	9	14	29	23	21	11	2	—	—	—	—	—	—	—	113
F_4 Type 9 × Type 51																										
738—15—1913	19	3	7	11	28	23	13	12	4	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	104
738—19—1913	?	—	4	12	28	37	9	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	91
738—81—1913	21	4	15	25	26	15	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	98
738—76—1913	23	—	—	—	—	—	1	14	10	20	30	11	7	2	—	—	—	—	—	—	—	—	—	—	—	95
738—96—1913	24	—	—	—	—	5	7	7	12	13	16	10	11	7	7	4	1	—	—	—	—	—	—	—	—	100
738—58—1913	25	—	—	5	8	13	10	13	21	7	12	7	2	1	—	—	—	—	—	—	—	—	—	—	—	99
694—103—1913	?	—	—	—	1	5	—	8	12	12	8	16	8	9	7	7	3	5	4	—	1	—	—	—	—	106
694—10—1913	?	—	—	—	—	1	3	4	7	6	12	11	14	10	13	7	4	4	—	1	—	1	—	—	—	98
694—1—1913	?	—	—	—	—	—	—	5	4	16	28	28	15	5	4	—	—	—	—	—	—	—	—	—	—	105
694—23—1913	?	—	—	—	—	—	—	—	—	—	—	—	1	2	7	10	16	16	15	22	16	9	3	3	1	121

Average No. of Leaves Type 9—1912, 21·8.
Type 9—1913, 21·1.
Type 51—1912, 28·4.
Type 51—1913, 29·5.

F_1 Type 9 × Type 51—1912, 24·4.
F_4 culture 738—19—1913, 20·4.
F_4 culture 738—81—1913, 19.4.
F_4 culture 694—1—1913, 26·5.

practically constant is further evidence that, within the same type, height and number of leaves are not correlated. This is a somewhat surprising result. It coincides, however, with the conclusion of Hayes, that the correlation between height and number of leaves was less than +.5.

The data as regards this character in the cross Type 9 × Type 51 are given in Table VIII. The F_1 generation was intermediate between the parents. The F_2 generation has a range far outside those of the parents, one of the plants having as many as forty leaves. That this is not due to accidental circumstances is shown by the reappearance of this phenomenon in one of the cultures in the F_4 generation, where the number of leaves varies from twenty-eight to forty. The eight cultures of the F_3 differed greatly in their range of variation; none were uniform. Two of these were continued in the F_4 generation, i.e., Nos. 738 and 694. From 738 two cultures were obtained, Nos. 738-81 and 738-19, which from their range of variation and the form of the curve appear to be uniform. The first has an average of nineteen leaves per plant, and a variation of seventeen to twenty-two. The latter culture, 738-19, is a replica of Type 9 as regards number of leaves. In the culture, derived from 694 only one can possibly be uniform, No. 694-1, but as the range of variation is somewhat large it may have originated from a heterozygote between two forms differing in one small factor. In either case it points to the occurrence of intermediate homozygotic combinations. Thus in the F_4 generation there have been isolated a culture (probably uniform) with a smaller number of leaves than either parents a culture with the same number of leaves as one parent, a culture which is either uniform with a number of leaves intermediate between both parents or a heterozygote between two intermediate forms, and a culture in which the majority of plants possess more leaves than either parent.

In the cross between Type 16 and Type 35 (Table IX), the F_1 is again intermediate, but approaches the parent with

Table IX.

Number of Leaves per Plant. Type 16 × Type 35.

		No. of Leaves in Parent.	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total No. of Plants
ype 35	1912				1	14	23	5	1																		44
ype 35	1913					5	11	10	7																		33
ype 16	1912													1	11	16	15	2									45
ype 16	1913														3	9	26	19	8	2							67
F_1 Type 16 × Type 35	1913									2	9	23	22	13													69
F_2 Type 16 × Type 35	1912					5	19	44	45	23	54	56	27	14	23	27	5	4									346
F_3 Type 16 × Type 35																											
	163—1913	24					1	1	5	7	20	22	22	7	4	3	2										94
	202—1913	24							5	9	22	45	13	9	1												104
	9—1913	25								6	10	20	15	21	15	13	2	3									105
	27—1913	26								2	12	10	13	13	9	6	5	4	1								75
	231—1913	26								2	4	10	15	15	18	17	12	8	6								107
	15—1913	27						2	2	4	9	11	25	11	18	7	5	5	2								101
	8—1913	27								1	5	8	6	17	25	21	20	4									107
	142—1913	27									9	8	27	25	21	11	7										108
	251—1913	28											1	7	14	31	34	11	7								105
	35—1913	29											4	16	15	30	16	10	6	5	2						104
	190—1913	30											1	8	18	33	30	10	8	2							110

Average No. of Leaves per Plant Type 16—1912, 30·1.
Type 16—1913, 31·4.
Type 35—1912, 20·8.
Type 35—1913, 21·6.

F_1 Type 16 × Type 35—1913, 26·5.
F_2 culture 251—1913, 30·4.
F_3 culture 190—1913, 30·4.
F_3 culture 202—1913, 25·8.

the larger number of leaves. The limits of the F_2 generation are as great as those of the parents combined, but no greater. The curve obtained from its graphic representation (Plate XIV) points to distinct segregation, as do also the results obtained from the F_3 cultures. The following cultures appear to be uniform, Nos. 251 and 190, with an average number of thirty leaves per plant, and 202, with an average of twenty-six. This is another instance of the production of a plant possessing a number of leaves intermediate between those of the parents and breeding true.

Table X gives the results in the cross Type 23 × Type 38, which are very similar to those in Table IX. The F_1 generation again approaches the parent with the greatest number of leaves. Distinct segregation occurs in the F_3, but no cultures breeding true were found.

As regards the principles underlying the inheritance of the number of leaves per plant, there seems no doubt that this is a definite inheritable character, and that on hybridization segregation occurs with the formation of new homozygotic combinations. In dealing with the mode of inheritance we are confronted with the same difficulty as in the case of the height, namely, the impossibility of a plant without leaves. Hayes supposes a basal condition of x leaves which occurs in all tobacco plants with a number of small interchangeable factors, each of which may represent two leaves. Thus the same number of leaves per plant may in reality have been caused by different combinations of characters, i.e., twenty-two leaves may be x + AAbb or x + BBaa.

There is nothing in the results obtained in these investigations to contradict this hypothesis of a basal number of leaves combined with interchangeable factors. The results in the cross Type 9 × Type 51 appear to be a direct confirmation. But the form of the curves obtained in the F_2 generations point distinctly to the occurrence of factors of different values. If all the factors were more or less equal in value the form of the curve would be more uniform, and would not show such distinct modes.

Table X.

Number of Leaves per Plant. Type 23 × Type 38.

		No. of Leaves in Parent.	Number of Leaves. 17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total No. of Plants.
Type 23	1912		—	3	8	11	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25
Type 23	1913		—	1	8	17	13	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	43
Type 38	1913		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	5	9	11	4	1	—	—	—	35
F_1 Type 23 × Type 38	1913		—	—	—	—	—	—	—	—	—	—	7	15	15	11	—	—	—	—	—	—	—	—	—	—	48
F_3 Type 23 × Type 38																											
	104—1913	22	—	—	2	6	7	10	16	19	18	14	3	4	1	—	—	—	—	—	—	—	—	—	—	—	100
	159—1913	23	—	—	—	—	3	3	6	10	17	17	17	13	8	3	1	1	—	—	—	—	—	—	—	—	99
	213—1913	24	—	—	—	3	2	4	15	19	23	9	14	5	3	—	—	—	—	—	—	—	—	—	—	—	97
	204—1913	24	—	—	—	—	—	—	—	9	20	27	22	9	2	1	—	—	—	—	—	—	—	—	—	—	90
	155—1913	25	—	—	—	—	—	—	—	2	9	13	15	21	17	10	5	4	3	—	—	—	—	—	—	—	99
	117—1913	25	—	—	—	—	—	—	1	4	7	10	8	18	17	13	6	4	3	2	—	—	—	—	—	—	93
	6—1913	29	—	—	—	—	—	—	—	2	8	9	15	13	18	11	13	4	1	1	—	—	—	—	—	—	95
	9—1913	30	—	—	—	—	—	—	—	—	—	—	—	2	5	11	14	13	20	18	15	5	—	—	—	—	103
	111—1913	?	—	—	—	—	—	—	—	—	—	—	3	10	12	27	19	9	8	4	1	—	—	—	—	—	93

Average No. of Leaves per Plant Type 23—1912, 19·6.
Type 23—1913, 20·3.
Type 38—1913, 34·2.
F_1 Type 23 × Type 38—1913, 28·6.

4. THE ARRANGEMENT OF THE LEAVES ON THE STEM.

Besides the height and the number of leaves, the habit of growth of a tobacco plant depends on the arrangement of the leaves on the stem and on the inclination of the leaves, i.e., on their tendency to assume an upright or a drooping position. An economically profitable plant for India should possess a large number of upright leaves on a stem of medium height, the majority of the leaves being borne towards the base of the stem. The inheritance of the height of stem and of the number of leaves has been dealt with in sections 2 and 3. No definite results can be given as to the position of the leaves, but in cross Type 16 × Type 35, in which a form with drooping leaves was crossed with one in which the leaves are upright, distinct segregation with the formation of intermediates was observed. Similarly in culture 694-23 (Plate XVI) the upright character of the leaves of Type 51 was reproduced.

The results concerning the mode of inheritance of the arrangement of the leaves are not very complete, but some interesting observations were made. With regard to this character, the plants can be divided into three groups: (1) those which carry all their significant leaves at the base of the stem and in which the leaves consequently lie on the ground ; (2) those in which the majority of the significant leaves are borne near the base, the rest up the stem, and (3) those in which the leaves are borne at equal intervals up the stem. This latter condition, which may be termed the "ladder type," is well seen in Type 51 and its offspring, No. 740 (Plate XV). This particular arrangement does not depend on the number of leaves or on the height of the plant. Short and tall plants alike are found of this type. Type 16 is an example of a short plant, with equal short internodes ; culture No. 740 of one with equal, long internodes. In every case plants selected with this arrangement of the leaves have bred true as regards this

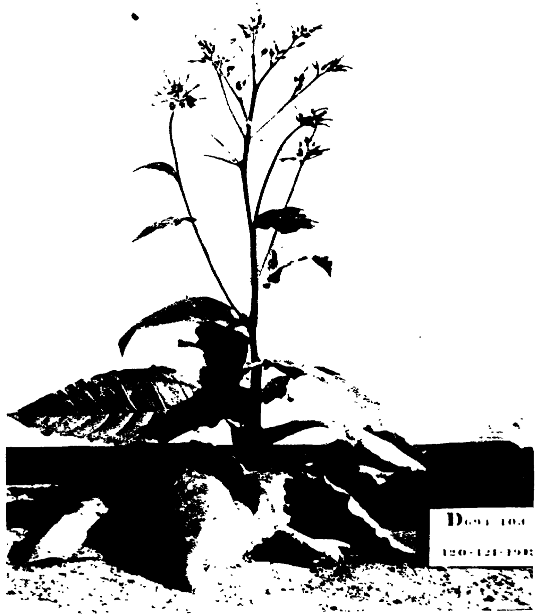
character. The F_3 cultures 190, 35, 15, 163 and 9, of Type 16 × Type 35 exemplified this.

The first arrangement in which all the leaves are carried at the base of the plant, and of which Type 9 is a good example, also does not depend on the number of leaves. In the F_4 culture 738-96, which bred true to this arrangement, the number of leaves varied from twenty-one to thirty-two, and apparently the plant found no difficulty in crowding these thirty-two leaves at the extreme base. The leaves were fairly narrow, otherwise the lower ones would have rapidly died from want of light and air. This rosette arrangement has never been met with in a very tall plant. It appears in plants of medium height (Plate XVI, 694-103-120), but the leaves are not quite so concentrated. The dwarf rosette forms have been bred true, but as yet no taller ones.

The second group, those plants in which the majority of the leaves are concentrated at the base, is a very variable one and contains a large number of different types which breed true. The difference in these types does not depend on the height, but appears to be influenced by large differences in the number of leaves. The same arrangement with twenty leaves and thirty-three leaves must appear dissimilar. The F_1 generation between Type 9 (rosette) and Type 51 (ladder) was of this type. It is interesting to note that in the F_3 generation besides rosette and ladder types, two different forms belonging to the second of the above groups have bred true. One with a few leaves at the base but which otherwise resembles the ladder type is shown on Plate XVI, 694-38-72. Another form with a great concentration of leaves at the base, 694-23-1, is shown on the same plate. The latter is an excellent type for economic purposes and it is hoped to obtain a useful tobacco from it. The fact that this culture, with such a profitable habit of growth for economic purposes, has been bred from two such useless forms as Type 9 and Type 51 is important.

69[illegible]-48-[illegible]

694-23 1.



694-103 [illegible]20.

HABIT. F_1 TYPE 9 × TYPE 51.

5. THE INSERTION OF THE LEAVES ON THE STEM.

In *N. tabacum* the leaves are amplexicaul and in many cases the lamina is decurrent. The length of this decurrent portion varies from .5 to 7 or 8 centimetres. Forms with non-decurrent leaves are also found. As this is one of the few characters in *N. tabacum* in which total absence of the character is possible, it has been investigated in some detail.

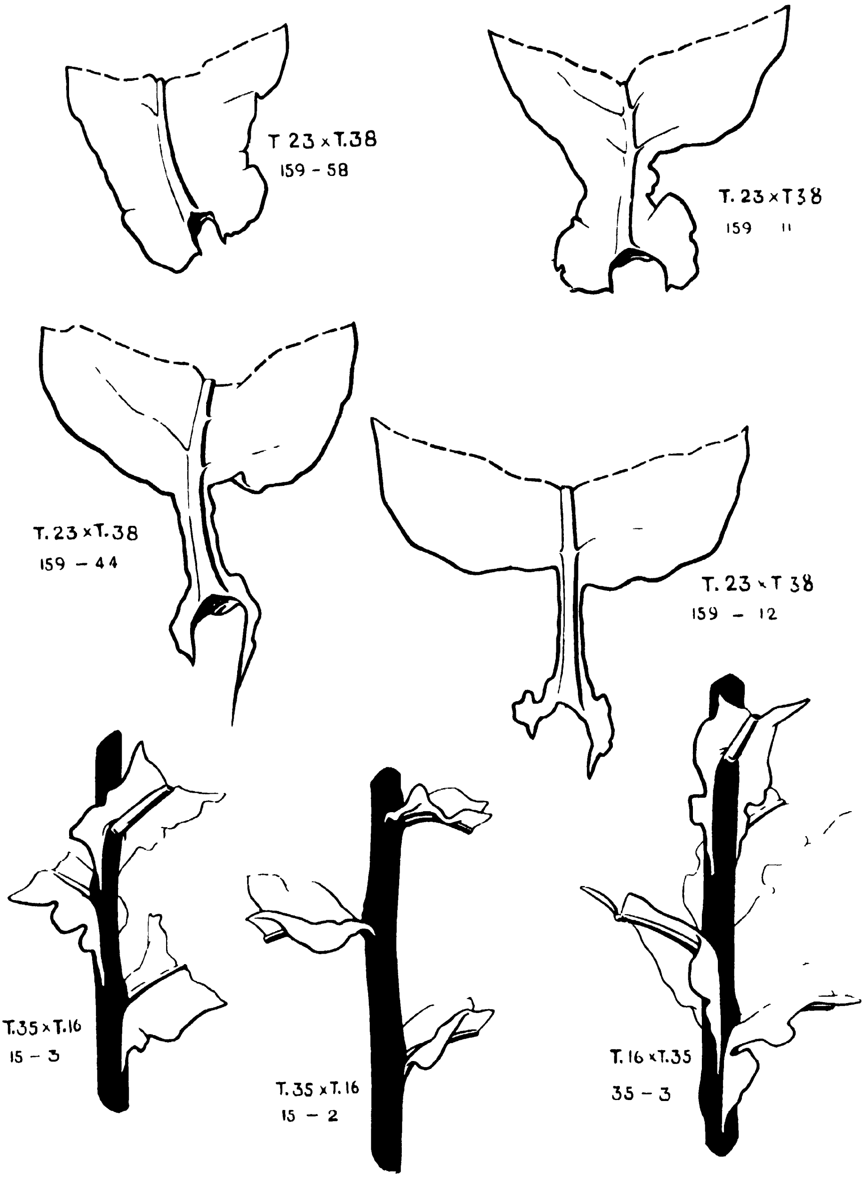
Particular attention was paid to the possibility of correlation between this and other characters such as the length of the internodes or the configuration of the base of the leaf, but as far as can be ascertained there is no relation between this character and any other. Table XI shows the lengths of the decurrent portion of the lamina of three leaves and the lengths of the three corresponding internodes in the F_3 culture 15 from the cross Type 16 × Type 35. It will be seen that there in no connection between the length of the internode and the length of the decurrent lamina. Two of the plants are figured on Plate XVII. Shortness of internode appears to have no effect in diminishing the length of the decurrent portion. Should the internode be shorter than the decurrent lamina, the latter simply grows on into the next internode past the next leaf (see Plate XVII, 35-3). At the base of the plant where the leaves are very concentrated it is true that this character cannot obtain its full expression, but there are always longer internodes above on which the real length can be observed. A limiting case might arise in which the number of leaves being very large, the plant very short and the decurrent portion very long, the latter was always stopped by the lamina of the next leaf, but such cases must be exceedingly rare, and none have been observed up to the present.

It also seems possible that the configuration of the leaf base might influence this character and that the lamina of a leaf with large auricles or a broad base would be more liable to grow down the stem. This has, however, not been found to be the case. No. 159-44, Plate XVII, shows a petiolate leaf

Table XI.

Length of Internode and of the Decurrent Portion of the Lamina. Type 16 × Type 35, culture 15.

Plant No.	Length of Internodes. 1	2	3	Length of Decurrent Portion. 1	2	3	Mean Length of Internode.	Mean Length of Lamina.	Plant No.	Length of Internodes. 1	2	3	Length of Decurrent Portion. 1	2	3	Mean Length of Internode.	Mean Length of Lamina.
19	8.0	6.5	7.0	3.4	3.2	2.9	7.2	3.2	57	6.0	5.7	5.7	3.7	4.7	4.8	5.8	4.4
44	6.7	8.0	9.3	6.2	3.3	4.0	8.0	4.5	66	8.2	7.8	6.5	4.4	3.4	4.0	7.5	2.9
36	9.0	8.5	7.0	6.4	5.5	5.7	8.2	5.9	27	9.5	8.7	8.8	5.1	5.5	6.2	9.0	5.6
73	6.1	6.6	6.1	7.0	4.1	3.5	6.3	4.9	76	4.9	4.2	4.6	4.2	4.4	4.1	4.6	4.2
1	4.0	4.6	4.0	2.6	2.0	2.2	4.2	2.3	37	6.8	7.7	6.1	5.2	5.0	6.9	6.9	5.7
60	5.0	3.9	4.0	2.0	2.0	1.9	4.3	2.0	98	9.6	7.0	7.5	5.4	3.9	3.8	8.0	4.4
83	6.4	5.7	6.0	3.2	3.0	3.2	6.0	3.1	104	6.3	6.2	6.7	5.5	7.0	5.4	6.4	6.0
91	5.9	5.2	4.6	3.0	3.2	2.7	5.2	3.0	10	5.6	5.1	5.5	4.8	4.6	4.3	5.4	4.6
20	4.9	4.8	4.1	2.3	2.0	2.1	4.6	2.1	32	5.0	4.9	4.9	4.1	5.0	4.5	4.9	4.5
47	7.2	7.4	7.1	5.3	6.2	5.9	7.2	5.8	6	8.0	6.9	6.8	4.2	4.1	4.3	7.2	4.2
33	7.3	6.5	5.2	2.3	2.1	2.1	6.3	2.2	106	8.7	9.2	8.2	3.4	3.6	2.7	8.7	3.2
16	4.7	5.4	5.5	3.0	4.2	4.5	5.2	3.9	107	8.1	8.5	7.2	7.1	6.1	5.1	7.9	6.1
23	6.9	6.2	5.1	2.4	2.6	2.8	6.1	2.6	85	5.9	5.3	5.5	1.7	1.9	2.1	5.6	1.9
39	5.3	5.9	4.5	4.9	5.2	4.7	5.2	4.9	199	4.5	4.4	4.3	2.4	2.2	1.6	4.4	2.1
21	5.1	5.2	4.4	5.1	4.7	4.2	4.9	4.7	68	7.9	7.5	6.5	6.8	5.0	6.0	7.3	5.9
42	5.3	5.6	4.7	3.4	2.6	2.4	5.2	2.8	102	6.7	7.0	6.6	4.6	4.5	4.9	6.8	4.7
2	6.7	6.0	6.4	1.4	1.8	2.1	6.4	1.8	77	7.5	7.6	6.9	6.2	6.5	8.3	7.3	7.0
84	7.2	6.2	5.5	2.7	2.6	4.0	6.3	3.1	87	8.0	8.3	7.7	2.4	3.1	3.3	8.0	2.9
92	7.3	6.9	6.4	3.9	4.4	4.2	6.9	4.2	18	3.2	4.8	3.7	2.2	2.0	2.1	3.9	2.1
34	6.2	6.5	5.6	2.7	3.0	2.6	6.1	2.8	78	5.8	5.3	4.3	3.2	2.7	3.0	5.1	3.0
29	7.2	6.5	5.5	3.9	4.5	3.9	6.4	4.1	62	4.5	4.5	3.6	4.0	4.4	4.2	4.2	4.2
50	5.0	4.2	4.3	3.7	3.5	3.4	4.5	3.5	9	4.4	4.7	4.2	3.4	3.6	4.0	4.4	3.7
49	9.3	9.1	8.4	5.6	5.4	6.3	8.9	5.8	69	7.6	6.7	6.6	3.2	4.7	3.6	7.0	3.8
65	7.2	6.9	7.0	7.7	7.6	7.2	7.0	7.5	95	4.1	3.7	4.0	4.6	4.4	4.4	3.9	4.5
8	4.5	4.2	3.3	2.7	3.2	3.1	4.0	3.0	14	4.5	4.9	3.9	2.9	3.1	2.7	4.4	2.9
58	5.5	6.1	7.5	5.2	5.0	4.1	6.7	4.8	89	6.0	5.4	5.0	4.7	4.6	4.6	5.5	4.6
63	7.0	5.7	5.5	4.9	3.6	4.0	6.1	4.2	59	6.2	7.2	6.3	4.7	5.5	4.9	6.6	5.0
71	7.2	7.3	6.8	3.5	4.2	4.3	7.1	4.0	94	8.4	9.0	7.2	2.6	3.6	3.0	8.2	3.1
81	6.8	6.2	6.7	7.3	6.4	7.4	6.6	7.0	61	4.7	5.4	4.6	1.5	1.6	1.8	4.9	1.6
90	6.3	7.6	5.3	6.3	5.2	5.7	6.4	5.7	88	9.1	8.7	7.2	4.3	4.1	3.9	8.3	4.1
80	6.6	6.6	5.2	3.2	3.5	3.7	6.1	3.5	17	8.5	6.9	7.4	5.2	8.3	5.5	7.6	6.3
100	4.9	5.1	4.7	2.7	3.9	3.8	4.9	3.5	105	7.3	7.8	6.8	3.0	3.5	3.0	7.3	3.2
24	6.0	6.2	6.1	1.7	1.9	1.4	6.1	1.7	13	6.5	6.9	5.4	5.6	6.5	6.1	6.3	6.1
26	10.6	9.3	9.1	5.8	5.3	5.2	9.7	5.4	74	6.4	6.8	7.2	4.1	4.1	3.5	6.8	3.9
12	4.4	4.3	4.1	2.6	2.7	3.0	4.3	2.8	72	6.0	4.7	5.3	1.6	2.3	2.4	5.3	2.1



DECURRENT LEAVES

with a long decurrent portion; No. 159-58 a broad leaf with a short one; No. 159-11, a leaf with large auricles and a short prolongation of the lamina.

Further, this character does not appear to be correlated directly with the width of the leaf.

Measurements were taken in two ways, firstly, by measuring a typical leaf on the living plant; secondly, by measuring three leaves on the plant when this had been uprooted for the observations on the height and number of leaves. The first method has the advantage that information on the inheritance of this character is available before the seed plants are chosen, the second is less fatiguing and more accurate. A large number of cultures have been examined by both methods and on normal plants either method gives good results. In this character a large amount of variation occurs, particularly in those leaves in which the decurrent portion is long. It is, however, a definitely inheritable character with distinct segregation (see Tables XIII, XV and XV). The approximate mean measurements of all the Indian types is given in Table XII (average of ten plants). It will be seen that the possibilities are numerous.

Table XII.

Length of the Decurrent Portion of the Lamina in the Types of *N. tabacum*.

	Cm.		Cm.		Cm.
Type 7	—	Type 3	1.5	Type 24	3.0
„ 9	—	„ 10	1.5	„ 43	3.1
„ 21	—	„ 5	1.6	„ 27	3.3
„ 12	.5	„ 17	1.9	„ 26	3.5
„ 20	.5	„ 18	2.0	„ 16	3.6
„ 6	.5	„ 1	2.0	„ 31	3.7
„ 13	.7	„ 42	2.3	„ 37	3.8
„ 11	.8	„ 2	2.5	„ 47	4.1
„ 14	.9	„ 35	2.5	„ 48	4.1
„ 36	1.1	„ 40	2.6	„ 30	4.5
„ 8	1.2	„ 39	2.6	„ 49	5.4
„ 23	1.3	„ 35	2.8	„ 51	6.0
„ 3	1.5	„ 41	2.9	„ 38	6.0

Table XIII gives the results obtained in the cross Type 9 (non-decurrent) × Type 51 (with an average of 6 cm.). The F_1 was intermediate between the parents and the F_2 covered the whole range between non-decurrent forms and those like Type 51. Several of the plants classed as non-decurrent in the F_2, however, gave rise to forms with decurrent laminas later (cultures 738 and 745). This may be due to the fact that in the early investigations the number of factors involved was not realized and no measurements of less than .5 centimetres were made. Great differences were observed in the F_3 generations, e.t., the cultures 738 and 132, but none of the cultures proved uniform. In 1912, unfortunately all plants in which the decurrent portion was shorter than 5 mm. were again classed as non-decurrent. Cultures 738 and 694 were continued to the F_4 generation. The results obtained from culture 738 will be considered first. Two plants which appeared similar to Type 9, were chosen for future cultivation, and four plants whose leaves were decurrent to varying amounts, 5, 7, 11 and 15 mm. Of the two cultures with non-decurrent leaves, one bred true and resembled Type 9. The other was a heterozygote. A detailed examination of Type 9 shows that occasionally the method of insertion of the leaves caused the lamina to be attached to the stem for about 3 mm. This makes it almost impossible to distinguish pure non-decurrent forms from the F_1 between non-decurrent leaves and those possessing the smallest factor for a decurrent lamina. In 1913 most careful measurements of all plants have been made especially in those cases where the value was below 5 mm. Three careful determinations were made in the case of all the cultures derived from 738, and the mean of these form the data given in Table XIV. The limits, within which the splitting takes place, are so small that it is very difficult to obtain really reliable information as to the extent and number of the factors, but there is no doubt of the difference between the cultures. It appears probable that two factors are involved, one giving a length of about .5 or .7 cm.; the other about 1.1 cm.,

Table XIII.

Length of the Decurrent Portion of the Lamina. Type 9 × Type 51.

			Parent Cm.	Less than .4	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	Total No. of Plants
Type 9		1912		52																							52
Type 9		1913		54																							54
Type 51		1912											2	6	9	13	8	8	2	3							51
Type 51		1913												2	7	13	16	5	1								44
F_1 Type 9 × Type 51		1913					1	20	30	7																	58
F_2 Type 9 × Type 51		1911		142	55	120	94	90	72	49	24	10	4	5	1	1		1									668
Type 9 × F_1 Type 9 × Type 51		1911		150	42	46	31	8		1																	278
Type 51 × F_1 Type 9 × Type 51		1911				4	11	23	40	22	32	32	22	12	1	4	1										204
F_3 Type 9 × Type 51	738	1912	Less than .4	46	2	42	48	8																			146
	745	1912	Less than .4	49		29	49	14	2																		143
	737	1912	1.0	1	12	24	41	27	13	9	4	4															135
	167	1912	2.5			1	5	34	36	13	7	1															97
	736	1912	3.0		1	3	16	28	18	32	15	7	4	1													125
	740	1912	3.0					1	8	22	34	30	22	6	4	3											130
	694	1912	3.5				3	13	18	21	17	18	5	5		1											101
	132	1912	Like T.51						1	4	17	22	31	18	13	5	4	1									116
F_4 Type 9 × Type 51	738 96	1913	Less than .4	108																							108
	738 19	1913	Less than .4	7	66	27	5																				105
	738 76	1913	.5		11	68	15																				94
	738 15	1913	.75		68	33	3																				104
	738 81	1913	1.2			64	33																				97
	738 58	1913	1.5			11	81	9																			101
	694 1	1913	1.3			1	21	54	23	1																	100
	694 103	1913	2.3			2	17	17	14	22	13	11	6														102
	694 38	1913	3.8				1	7	20	36	31	12	4														111
	694 10	1913	4.6						5	15	26	16	26	6	4	1											99
	694 23	1913	6.2						1	4	10	35	20	11	10	8											99

TABLE

Length of the Decurrent

				Parent	Length of the Decurrent Portion of the Lamina in Millimetres.										
				mm.	0	1	2	3	4	5	6	7	8	9	10
F_3 Type 9	Type 51	745	1912	Less than 5	49			1		16	1	11	10	1	14
F Type 9	Type 51	738	1912	Less than 5	46			2	30	2	10	19		15	6
F_4 Type 9	Type 51														
		738 19	1913	Less than 4			7	8	11	18	14	15	8	7	4
		738 76	1913	5						1	1	9	12	15	15
		738 15	1913	7 5				2	1	12	22	28	15	7	4
		738 81	1913	12									2	11	11
		738 58	1913	15											1
		694 1	1913	13											
Type 23			1913								1	1	1	1	3
F_3 Type 23	Type 38	155	1913	15									1	1	6
F_3 Type 16	Type 35	190	1913	14									6	2	12

or there may be two factors of .5 and .7 cm. with a combination of 1.2 cm. It will be seen from the graphic representations (Plate XIV) that 738-81 with a mode at 1.1 cm. is most probably uniform, and culture 15 with a mode at .7 cm. possibly so. The number of plants with non-decurrent leaves in culture 738-19 gives a ratio, total plants: those with non-decurrent leaves, 15: 1, which would also indicate the existence of two factors. Further observations will be made on this point, but on account of the small size, the difficulties of measurement and interpretation are very great. Culture 694 must be considered next. This culture has never given any plants with non-decurrent leaves. Two cultures appear to be uniform, 694-1 with an average length of the decurrent portion of 1.8 cm., and 694-23 with an average of 4.0 cm. The detailed measurements of the culture 694-1 are also given in Table XIV, and show by their range that this cannot possibly be identical with the combination of factors in the culture 738. As the parent plant of 694-23 was the plant with the longest and that of 694-1 the plant with the shortest decurrent portion in the F_3 culture 694, it is probable that 4.0 cm. the mean value of 694-23 represents the combination of the factor or factors of 694-1 with another or others. The existence of at least three or four factors which

XIV.

Portion of the Lamina.

Length of the Decurrent Portion of the Lamina in Millimetres.																				Total No. of Plants
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
15	9	8	1	3	1	1			1	1										143
8	5		2		1															146
5	3	2	1		1	1														105
17	9	5	6	3		1														94
4	3	2	1																	101
22	17	17	7	8	1															96
3	7	17	22	13	13	15	6	1	2			-								100
	1	2		11	3	5	18	2	16	1	17	9	2	6	4	2	1			100
1	8	8	6	5		3	1		2									—		44
1	5	14	9	6	2	4	5			1	3								–	58
4	11	20	9	9	3	11	11		6		2		1						1	108

combine to make up the length of the decurrent portion of the lamina in Type 51 is therefore probable.

The results in cross Type 16 Type 35 (Table XV), are also interesting. Here both parents have the same average value, and the range of variation in the F_1 generation is exactly similar to that of the parents. The length in the F_2 generation varies from .5 cm. to 6.5 cm., far beyond the limits of the parents. No plants with non-decurrent leaves were found, but this may have been due to the comparatively small number measured. In the third generation there were great differences among the cultures, and plants with non-decurrent leaves occurred in three cultures. The numbers in all these cases (cultures 231, 202, 27) point to a 63: 1 ratio and consequently to the existence of three factors in these particular cultures. Higher values were found in the F_2 than in these cultures indicating the existence of additional factors in the parents. This supposition is confirmed by the high values found in the F_3 culture 163. The large number of factors involved would explain the absence of plants with non-decurrent leaves in the F_2. The factors which are responsible for the length of the decurrent portion of the lamina in Types 16 and 35 respectively would seem to be entirely different, even though their external expression is identical.

Culture 163 probably represents the combination of all the factors in Type 16 and Type 35. The total variation is no greater than in Type 51. The average value in this culture is greater than the combined average values of Type 16 × Type 35, but this may be due to the added vigour due to hybridization. Further cultures will, it is hoped, put the matter beyond question, and any explanation must be tentative until these have been examined. Culture 190 is probably uniform with regard to this character.

The cross Type 23 × Type 38 (Table XVI) is similar to that between Type 9 and Type 51, except that neither parent has non-decurrent leaves. The F_1 is intermediate and the range of variation in the F_2 generation is the same as that covered by both parents. It would seem therefore as if the same combination of factors was common to both parents with the addition of extra factors in one parent. Culture 155 is uniform and like Type 23, culture 104 is possibly uniform and like Type 38, but this cannot be assumed safely until further cultures are raised, as the variability is somewhat great. The parent Type 38 and the F_1 generation exhibit very great variation in the same plant.

6. VENATION OF THE LEAVES.

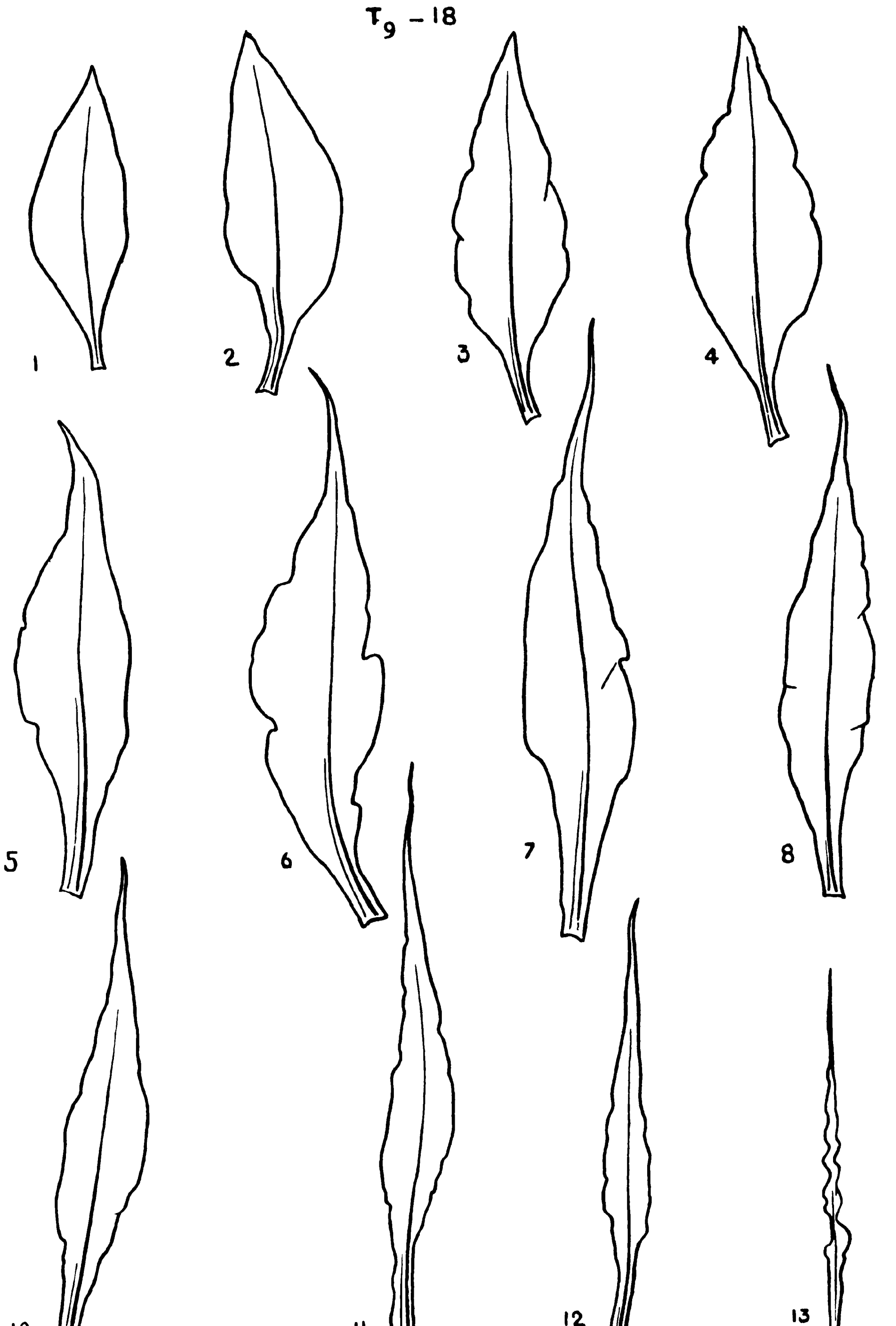
The characters of the lamina itself will now be considered and of these the venation has proved to be the most constant and easily measured. A few words of explanation as regards the choice of the material are necessary, and the following explanation refers to all measurements on the leaves themselves. The leaves of a tobacco plant are not all of the same kind, the lower or ground leaves are very much alike in all the types and are not characteristic of the variety. They are almost invariably flat, and have a venation of 60°. This is the case even in Type 9, in which the upper leaves are twisted by excess of undulation. These ground leaves pass by a fairly rapid gradation into the significant leaves, which are typical of the variety, and comprise most of the leaves on the plant. The significant leaves increase

Table XV.

Length of the Decurrent Portion of the Lamina. Type 16 Type 35.

			Parent Cm	Less than ·4	·5	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0	Total No of Plants
Type 16		1912						11	31	23	9																74
Type 16		1913						3	12	18	4																37
Type 35		1912						15	26	20																	61
Type 35		1913						15	18	2																	35
F_1 Type 16	Type 35	1913						20	35	9																	64
F_2 Type 16	Type 35	1912			7	19	37	36	50	32	33	19	12	7	6	2	2										262
F Type 16	Type 35																										
	142	1913	·5		15	63	27	2																			107
	231	1913	·8	2	8	40	25	20	7	4		1															107
	202	1913	1·2	3	8	63	10	16	11	14	7	5		2	2												141
	27	1913	1·2	2	22	38	20	16	7	2	2	1															110
	251	1913	1·3		10	51	40	6																			107
	190	1913	1·4			35	52	19	1																		107
	8	1913	3·3					1	12	11	21	17	18	9	9	5	1										104
	200	1913	3·5				1	13	27	27	20	10	4	1	2	1											106
	9	1913	3·8						1	11	22	27	28	27	10	8	4	1									139
	15	1913	3·8				4	8	8	10	10	17	13	11	9	4	7	3	2								106
	35	1913	5·5						1	1	4	11	12	12	13	8	14	9	7	5	2	3	2				104
	163	1913	6·8										1	3	15	28	22	13	11	6	1						100

slowly in size from the base and then diminish at the top of the plant, the diminution increasing very rapidly at the end. The leaves in the centre of the plant are approximately uniform in most of the types. Above the significant leaves come a few very small leaves which vary greatly in shape. In some of the broad-leaved types, they are small replicas of the large leaves; in types with lanceolate leaves they are linear; while in many cases they may be linear even if the significant leaves are not lanceolate. In Tables XVII, XVIII, and XIX detailed measurements are given of all the leaves on three plants of each of the parents. Unfortunately, by the time the plant is mature, the lower leaves have become damaged. The large number of fairly uniform leaves in the centre of the plant is, however, evident. Type 9 (Table XVII and Plate XVIII) is an example of an extreme case in which no two leaves are alike. The best material for all leaf measurements is undoubtedly to be found in the central leaves, which are practically uniform, and all the measurements in this paper have been taken on such typical leaves. It is impossible to choose any definite leaf (for example, the tenth leaf) suitable to all plants owing to the variations in the number of leaves per plant, but it is quite easy with practice to pick out the middle portion of the plant by eye and to select a typical leaf in this position. The tables show that in this region of the plant there are a large number of leaves, all of which are suitable. Measurements carried out on the parents by taking a typical leaf from a large number of plants have shown that the method is most satisfactory. The usual practice of obtaining the average between the bottom, the middle and the top leaf is open to many objections and would be quite unsuitable for the kinds of tobacco grown in India. It presupposes a uniform change in the size of the leaves on the plant, and takes no account of the large number of uniform leaves in the centre of the plant, which vary in their effect on the average with the number of leaves per plant, and the type of the plant. Moreover, the determination of the top leaf is necessarily arbitrary. The real top leaves are far too small



THE LEAVES OF A SINGLE PLANT (TYPE 9).

Table XVI.

Length of the Decurrent Portion of the Lamina. Type 23 × Type 38.

		Parent. Cm	Length of Decurrent Portion of the Lamina in Centimetres: 4	5	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0	Total No of Leaves.
Type 23	1912		—	—	26	45	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	74
Type 23	1913		—	—	5	18	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	26
Type 38	1912		—	—	—	—	—	—	—	—	2	3	14	14	14	14	15	2	—	—	—	—	—	—	—	78
*Type 38	1913		—	—	—	—	—	—	—	—	—	—	—	3	1	10	11	6	4	2	—	—	—	—	—	37
*F_1 Type 23 × Type 38	1913		—	—	—	—	—	2	7	13	9	11	3	2	—	1	—	—	—	—	—	—	—	—	—	48
F_2 Type 23 × Type 38	1912		—	—	9	9	32	34	54	41	44	33	25	20	14	7	4	5	3	—	—	—	—	—	—	343
F_3 Type 23 × Type 38																										
204	1913	1 3	—	—	15	31	31	11	8	2	—	—	—		—	—	—	—		—	—	—	—	—	—	98
155	1913	1 5	—	—	14	25	9	—	—	—	—	—	—			—	—	—		—	—	—	—	—	—	48
*117	1913	2 6	—	—	2	13	20	17	13	10	13	1	3	1		—	—	—	—	—	—	—	—	—	—	93
159	1913	2 9	—	—	—	9	32	26	21	7	5	5	3	1	1		—	—	—	—	—	—	—	—	—	110
6	1913	4 5	—	—	1	—	6	15	20	18	15	14	9	7	3	2	2	—	—	—	—	—	—		—	112
213	1913	4 5	—	—	1	4	12	16	20	19	21	3	5	3	—	—	—	—	—	—	—	—	—	—	—	104
*9	1913	—		—	—	—	2	13	18	15	20	14	8	3	6	2	—	—	—	—	—	—	—	—	—	101
*111	1913	6 6	—		—	—	—	3	9	11	16	7	9	10	4	11	5	5	3	2	—	—	1	—	—	96
*104	1913	7 2	—	—	—	—	—	—	—	—	—	1	10	15	11	16	17	14	5	5	1	2	—	—	—	97

In the plants marked * the values given are the mean of three determinations.

Table XVII.

Dimensions of Lamina. Types 9 and 51.

(Measurements in Centimetres)

No. of Leaf.	Venation.	Breadth.	Length.	Length. / Breadth.	Venation.	Breadth.	Length.	Length / Breadth.	Venation.	Breadth.	Length.	Length. / Breadth.
						Type 9.						
		Plant 1.				Plant 2.					Plant 3.	
1	Damaged				Damaged				Damaged			
2	"				"				"			
3	"				"				"			
4	40°	14.6	38.5	2.6	35°	12.8	33.8	2.6	35	11.6	31.5	2.7
5	30°	15.3	44.0	2.9	40°	16.0	42.0	2.6	40	12.6	39.0	3.1
6	40°	17.6	51.7	3.0	40	15.0	45.4	3.0	40	15.0	48.0	3.2
7	45°	17.8	57.0	3.2	45°	17.9	49.0	2.8	45	17.0	50.6	3.0
8	45°	15.7	56.0	3.5	50°	15.0	53.4	3.5	50	14.0		
9	50°	17.2	70.1	4.1	45°	17.4	64.1	3.7	45	13.2	58.0	4.4
10	50°	11.7	65.3	5.6	50°	14.7	70.2	4.8	50	12.3	59.7	4.8
11	50°	14.3	60.0	4.2	45°	11.2	60.3	5.4	50	11.5	61.0	5.3
12	50°	14.9	71.3	5.0	50	12.0	70.0	5.8	45	12.1	72.0	6.0
13	50°	9.3	65.0	7.0	50°	10.6	63.4	6.0	50	10.7	53.5	5.0
14	50°	8.3	63.5	7.6	45°	8.8	69.7	8.0	45	7.0	59.5	8.5
15	55°	8.2	67.0	8.2	50°	6.1	52.5	8.6	45	7.1	65.8	9.3
16	50°	4.5	53.0	11.8		2.9	44.6	15.3		5.0	53.8	10.8
17		3.2	51.5	16.1	remainder not measured					3.4	46.0	13.5
18	remainder not measured.									remainder not measured		
						Type 51.						
		Plant 1.				Plant 2.					Plant 3.	
1	Damaged				Damaged				Damaged			
2	"				"				"			
3	"				"				"			
4	"				"				"			
5	75	13.0	37.0	2.8	75	17.4	34.5	2.0	"			
6	75°	17.9	33.7	1.9	70	17.6	35.9	2.0	70	17.3	35.0	2.0
7	75	19.1	37.0	1.9	75	23.2	42.8	1.8	75	18.4	36.4	2.0
8	80°	21.4	42.0	1.9	75	23.2	44.7	1.9	70	20.7	41.3	2.0
9	75	21.5	42.3	1.9	75	26.7	48.0	1.8	75	24.7	47.5	1.9
10	80	23.9	44.3	1.8	80	26.8	48.8	1.8	80	23.8	46.1	1.9
11	75	24.2	48.7	2.0	80	24.6	48.1	1.9	80	25.3	47.1	1.9
12	80°	24.7	46.0	1.9	80	[illegible]7.1	50.5	1.9	80	25.4	47.4	1.9
13	80	23.8	46.9	2.0	80	27.6	48.8	1.8	80	26.8	48.6	1.8
14	80	25.6	46.3	1.8	85	29.0	49.3	1.7	80	25.9	47.2	1.8
15	80	27.1	46.8	1.7	75	28.3	45.9	1.6	80°	25.6	46.7	1.8
16	80°	25.3	47.2	1.9	80	26.4	47.0	1.8	80	25.7	44.8	1.7
17	85	26.0	43.1	1.7	80	27.7	45.2	1.6	80	27.1	46.7	1.7
18	85°	22.5	40.7	1.8	80	28.8	43.4	1.5	80	25.0	42.6	1.7
19	85	24.2	40.4	1.[illegible]	85	24.0	42.0	1.75	80	24.2	40.4	1.7
20	85°	24.0	39.2	1.6	80	26.6	41.8	1.6	85°	[illegible]	39.2	1.8
21	85°	20.8	36.8	1.8	80	24.9	39.4	1.6	80°	[illegible]	38.0	1.6
22	80°	23.5	34.2	1.5	80	26.[illegible]	39.0	1.5	80°	21.7	35.3	1.6
23	80°	19.8	32.7	1.[illegible]	75	21.8	34.3	1.6	85°	20.3	32.8	1.6
24	80°	18.3	30.8	1.[illegible]	80	15.3	27.0	1.8	80	18.9	28.6	1.5
25	75°	15.5	25.2	1.6	80	14.6	24.6	1.7	70°	13.4	24.6	1.8
26	75°	9.9	18.8	1.9	70°	8.4	18.0	2.1	70°	9.4	17.8	1.9
27		6.8	14.8	2.2		5.5	14.0	2.5				
28	remainder not measured				remainder not measured				remainder not measured			

Table XVIII.

Dimensions of Lamina. Types 35 and 16.

(Measurements in Centimetres)

No. of Leaf	Venation	Breadth	Length	Length / Breadth	Venation	Breadth	Length	Length / Breadth	Venation	Breadth	Length	Length / Breadth
						Type 35.						
		Plant 1				Plant 2				Plant 3		
1	Damaged				Damaged				Damaged			
2												
3												
4												
5					70	18.3	32.3	1.8	65	16.7	28.6	1.7
6	70	22.1	31.1	1.4	70	24.0	35.5	1.5	65	20.6	35.0	1.6
7	75	27.4	34.3	1.3	70	24.7	38.7	1.6	70	25.4	39.0	1.5
8	80	26.8			75	31.0	45.5	1.5	70	26.3	40.8	1.5
9	80	31.8	44.3	1.4	80	33.1	49.0	1.5	75	25.3	39.8	1.6
10	80	25.5	45.5	1.8	80	25.5	45.6	1.5	80	31.0	49.2	1.5
11	80	31.0	48.7	1.6	80	34.8	52.6	1.5	80	30.4	50.0	1.6
12	80	30.7	48.0	1.6	80	25.1	40.4	1	80	28.4	48.2	1.7
13	80	28.1	45.3	1.6	80	30.8	44.4	1.[illegible]	80	33.0	52.3	1.6
14	80	33.3	49.1	1.5	75	35.8	54.4	1	80	26.7	43.6	1.6
15	80	29.0	41.2	1.4	80	29.2	43.3	1.5	80	30.5	49.0	1.6
16	80	32.3	46.5	1.4	80	32.2	46.1	1.5	80	28.0	41.9	1.5
17	80	29.7	39.5	1.5	85	26.8	35.5	1.5	80	1[illegible].3	[illegible]3.1	1.6
18	80	22.7	33.2	1.5	85	16.4	25.5	1.6	80	1[illegible].5	[illegible]0.9	1.6
19	80	20.0	29.0	1.5	75	11.1	19.6	1.8	75	9.8	19.0	1.7
20	75	12.3	20.4	1.7	remainder not measured				60	5.0	12.8	2.4
21	60	4.8	12.8	2.7					remainder not measured			
22	remainder not measured											
						Type 16						
		Plant 1				Plant 2				Plant 3		
1	Damaged				Damaged				Damaged			
2												
3												
4					60	6.1	21.3	[illegible]				
5					Damaged							
6	50	7.8	30.8	4.0	60	7.8	28.0	[illegible]	55	8.2	23.7	[illegible]
7	55	7.0	25.0	3.6	50	7.5	30.8	4.1	60	8.6	31.2	3.6
8	50	9.1	35.6	3.9	[illegible]0	9.0	36.6	4.1	[illegible]0	9.7	[illegible]0	4.0
9	55	8.7	36.2	4.2	[illegible]0	8.8	31.7	[illegible]	60	[illegible]8	[illegible]8.7	4.0
10	50	10.7	43.1	4.0	55	[illegible].1	41.7	4.6	55	10.7	41.2	3.9
11	50	10.2	41.7	4.1	45	9.5			[illegible]0	10.5	46.3	4.2
12	55	11.0	46.3	4.2	[illegible]0	9.9	41.9	4.2	55	12.0	45.7	3.8
13	50	12.5	51.6	4.1	50	10.5	44.6	4.2	[illegible]0	12.4	48.5	3.9
14	45	12.2	47.4	3.9	50	10.1	41.0	4.1	[illegible]	11.9	48.1	4.0
15	45	11.7	52.2	4.5	55	10.5	45.4	4.1	[illegible]0	12.[illegible]	[illegible]	[illegible].9
16	50	11.1	46.9	4.2	50	10.4	45.6	4.2	[illegible]0	12.5		
17	50	12.1	49.1	4.1	50	10.5	44.1	4.2	55	11.5	45.7	4.0
18	50	13.0	51.7	4.0	50	11.5	43.8	3.8	[illegible]0	12.8	50.5	3.9
19	[illegible]0	12.4	48.3	3.9	50	9.7	41.7	4.3	50	11.3	48.8	4.3
20	50	13.0	51.5	4.0	50	10.0	42.7	4.3	50	12.3	4[illegible].0	[illegible].8
21	45	11.4	48.1	4.2	50	10.0	41.4	4.1	50	10.5	42.0	4.0
22	55	11.8	48.3	4.1	50	9.7	40.0	4.1	60	10.5	40.[illegible]	3.8
23	50	12.0	46.1	3.9	50	[illegible].2	38.9	4.2	50	10.5	43.8	4.2
24	50	9.8	40.4	4.1	50	8.6	37.5	4.4	55	9.5	39.0	4.1
25	50	10.6	39.3	3.7	50	8.5	38.9	4.6	70	9.0	36.[illegible]	4.0
26	45	7.0	31.6	4.5	50	7.7	34.9	4.5	55	9.2	[illegible]	4.0
27	45	5.7	27.0	4.7	45	6.8	32.5	4.8	50	6.5	28.0	4.3
28		2.9	19.6	6.8	45	6.2	29.1	4.7	50	5.4	24.8	4.6
29	remainder not measured					4.4	21.8	5.0		2.4	16.8	7.0
30					remainder not measured				remainder not measured			

Table XIX.

Dimensions of Lamina. Types 23 and 38.

(Measurements in Centimetres.)

Type 23.

No. of Leaf.	Plant 1. Venation.	Breadth.	Length.	Length. / Breadth.	Plant 2. Venation.	Breadth.	Length.	Length. / Breadth.	Plant 3. Venation.	Breadth.	Length.	Length. / Breadth.
1	Damaged				Damaged				Damaged			
2	"				"				"			
3	"				"				"			
4	"				"				"			
5	"				"				70°	18.2	33.5	1.8
6	65°	13.2	33.7	2.6	70°	22.0	44.8	2.0	65°	22.5	41.8	2.0
7	70°	19.2			70	25.1	51.0	2.0	70°	23.4	48.9	2.1
8	70°	23.0			70	26.8	56.6	2.1	75°	28.2	54.5	1.9
9	65°	24.6	55.0	2.2	75	28.8	60.6	2.1	70	28.4	62.0	2.2
10	70°	27.0	66.0	2.4	75	30.5	72.1	2.4	75	28.1	61.5	2.2
11	70°	27.0	60.5	2.2	75	27.4	69.4	2.6	75	24.6	58.7	2.4
12	70°	26.4	62.5	2.3	75	27.0	63.0	2.3	70	26.4	62.7	2.4
13	75	27.5	62.5	2.3	70°	26.1	61.0	2.3	75	25.7	57.4	2.2
14	70	21.9	56.7	2.5	70	22.3	55.7	2.5	70	23.0	52.0	2.3
15	65	23.8	55.1	2.3	65	20.9	50.0	2.4	75	17.5	40.3	2.3
16	70°	18.2	43.2	2.3	70	13.7	40.5	2.9	70	10.7	33.8	3.2
17		5.6	26.4	4.7		7.3	16.7	2.3		6.2	29.7	4.8
18	remainder not measured.				remainder not measured.				remainder not measured.			

Type 38.

No. of Leaf.	Plant 1. Venation.	Breadth.	Length.	Length. / Breadth.	Plant 2. Venation.	Breadth.	Length.	Length. / Breadth.	Plant 3. Venation.	Breadth.	Length.	Length. / Breadth.
1	Damaged				Damaged				Damaged			
2	"				"				"			
3	"				"				"			
4	"				"				"			
5	"				"				"			
6	"				65	31.6	43.0	1.4	65	24.7	35.5	1.4
7	"				65°	32.0	42.8	1.3	60	28.4	43.3	1.5
8	65	25.7	33.2	1.3	65°	[illegible]	52.3	1.5	65	32.6	48.3	1.5
9	60°	24.5	37.5	1.5	65	40.7	59.5	1.5	60	36.4	55.1	1.5
10	65	33.3	45.8	1.4	60	34.6	56.1	1.7	65	33.6	56.0	1.7
11	65°	35.4	52.5	1.5	65	38.7	62.1	1.6	65	38.1	58.8	1.5
12	60°	32.0	52.0	1.6	65	39.7	63.2	1.6	65	36.5	63.7	1.7
13	65°	35.5	55.2	1.6	65	[illegible]	56.1	1.8	65	33.2	57.9	1.7
14	60°	36.0	60.8	1.7	65	38.6	63.0	1.6	65	39.1	66.2	1.7
15	65	34.0	57.6	1.7	65	29.1	51.7	1.8	60	31.2	58.5	1.9
16	65°	35.5	58.6	1.7	65	31.5	55.8	1.8	65	34.5	60.8	1.8
17	60	27.4	52.0	1.9	60	38.3	65.0	1.7	60	37.4	59.5	1.6
18	65°	29.8	50.5	1.7	65	28.6	49.9	1.7	60	29.6	51.0	1.7
19	60	34.2	56.0	1.6	65	34.5	55.6	1.6	60°	35.3	56.4	1.6
20	60°	30.0	52.2	1.7	65	32.3	52.4	1.6	65°	32.5	49.8	1.5
21	60°	25.2	47.1	1.9	65	27.0	44.2	1.6	60	[illegible]	51.2	1.6
22	65°	27.7	46.6	1.7	60	30.2	48.1	1.6	65°	[illegible]	48.2	1.6
23	60°	27.0	45.1	1.7	65	23.7	39.8	1.7	65°	23.3	38.0	1.6
24	60°	24.4	43.8	1.8	65°	18.8	33.6	1.8	60°	23.3	39.5	1.7
25	60°	19.7	36.6	1.9	60°	25.2	42.3	1.7	60°	20.8	32.3	1.6
26	60°	18.3	33.2	1.8	60°	16.4	28.1	1.7	65°	14.9	23.5	1.6
27	60°	20.3	34.5	1.7	65°	15.2	25.4	1.7	60°	14.1	22.6	1.6
28	65°	15.9	27.2	1.7	60°	10.3	18.6	1.8	remainder not measured.			
29	65°	12.5	20.0	1.6	remainder not measured.							
30	60°	9.5	16.7	1.8								
31	remainder not measured											

for measurement and in many types the change between these and the significant leaves is very gradual. It is probable that in America the general uniformity of the kinds grown makes this method more applicable.

The actual procedure adopted in these investigations was as follows. Very small cardboard labels were prepared with the number of the plant and culture, and these were threaded with fine copper wire. These labels could be readily affixed to the leaf by passing the ends of the copper wire through the mid-rib, and bending them flat on the under side. The individual leaf chosen by the investigator for measurement was immediately labelled in this manner while on the plant. The leaves could then be removed and measured in some convenient place. The leaf after measurement was pressed with the label still attached, and thus a complete record of all the plants examined has been preserved. It is hoped to use this material in disentangling the factors which are concerned in the shape of the leaf. This method of attaching a label, which lies flat on the mid-rib, and therefore interferes with no measurement of the leaf while still on the plant, has proved most useful. The labour of preparing these labels, threading the wire, and the subsequent drying of the leaves, however, would not be possible for several thousand plants except for the cheap labour available in India. A second and a third leaf can be removed immediately above or below the first one chosen.

The venation of the leaves was determined by measuring the angle between the mid-rib and the lateral vein with a horn protractor. Only differences of 5° were noted. Experience showed that such determinations gave good results, and that the error generally was not more than $\pm 5°$. These measurements were carried out in two ways, either while the leaf was still attached to the plant or on the detached leaf which had been selected for other measurements. The first method has the advantage that all the leaves can be examined in a general manner by eye at the same time as the measurements are made ;

the second, that all the measurements such as width, length and venation are made on the same leaf. Comparative determinations on the same cultures by both methods give similar results. In most cases in 1913, the data given are the mean of two determinations, but experience shows that where time is limited one careful determination is quite sufficient. The difference between the determinations was not greater than the error of measurement.

The angle of venation appears to be extraordinarily constant for any one type (see Table XVII) and to be largely independent of the shape and width of the leaf. This is shown very well by Type 9, in which the angle remains constant at 50°, while the shape and width of the leaves varies greatly. An examination of Table XX shows that the angle of venation in the Indian types varies from 35° to 90° and that all the intermediate grades occur. The smallest angle, 35°, is found on a comparatively broad leaf. In Table XXI the relation between the venation and the shape of the leaf as expressed by the ratio length/breadth of the leaf is shown for the F_2 generation of Type 16 and Type 35, and also for all the Indian types on

TABLE XX.

Venation and ratio $\frac{\text{length}}{\text{breadth}}$ of the leaf in the various types of *N. tabacum*

Venation			Length/Breadth	Venation			Length/Breadth	Venation			Length/Breadth	Venation			Length/Breadth
35°	Type	19	2 4	50°	Type	6	4 1	60–65	Type	38	1 7	75°	Type	23	2 3
40°	,,	7	4 1		,,	9	3 6	65		33	1 9			37	2 7
	,,	8	4 4		,	16	4 1	70		21	2 6		,,	41	2 1
	,,	10	4 1		,,	1	3 0		,,	34	2 2			39	2 0
	,,	11	3 5		,,	27	2 6			39	1 9	80		35	1 6
	,	12	3 3	55	,	25	2 8		,	40	2 1			47	1 9
	,,	13	3 0	60°	,,	[illegible]	[illegible]			42	2 1		,,	48	1 9
	,,	14	3 8		,,	6	2 4			43	2 2		,,	51	1 9
	,,	20	2 6		,	30	2 4			44	2 2	90°	,,	50	1 8
	,,	21	2 8		,,	31	2 1		,,	45	2 2				
45°	,,	22	2 3		,,	36	2 0		,	38·	1 8				
					,,	46	2 6								

Table XXI.

Venation and ratio $\frac{\text{length}}{\text{breadth}}$ in F Type 16 × Type 35.

Ratio $\frac{\text{length}}{\text{breadth}}$	Size of Angle 40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	No. of Plants
1·7						1			1			2
1·8						1		1	1		1	4
1·9						6		3	4	2	1	16
2·0					4	3	7	6	12	4	1	37
2·1		1		2	9	8	5	5	4	7	1	42
2·2		1	5	4	7	6	19	9	8	1	1	61
2·3		1	2	3	13	8	8	3	4			42
2·4			4	8	26	7	13	6	4			68
2·5		1	4	11	10	5	9	3	2			45
2·6	1	1	8	7	9	7	2	1		—		36
2·7		2	6	2	4	5	4		1			24
2·8		1	10	4	5	3	1	1	1			26
2·9			1	1	2	3			1			8
3·0		2	3		4	1	—					10
3·1		2	3	1	2	1	1					10
3·2		1	3		1							5
3·3			3	2								5
3·4			1	1								2
3·5				1	1							2
3·6				1								1
3·7												
3·8												
3·9								—				—
4·0												
4·1			1									1
Total	1	13	54	48	97	65	69	38	43	14	5	447

Table XX. It will be seen that there is no true correlation between these two characters, and this is confirmed by many of the F_3-cultures in which the venation was constant, but the shape of the leaf very variable -culture 202 and many others. There does, however, seem to be a limit to the occurrence of the higher angles. Those above 75° are only met with in leaves with small ratios. A more detailed examination of the venation affords a possible explanation of this, for that there is no incompatibility between a large angle and a small ratio, is shown by the banana leaf. There is a striking difference in the leaves of the tobacco between the behaviour of the lateral veins which arise at an acute angle and those in which the angle is large. The

former always go straight to the margin, which they naturally meet obliquely, while the latter curve at this point and run almost parallel to the margin. This may be to avoid rupture of the lamina, or it may enable the food channels to serve a larger portion of the leaf for in the case of the acute-angled venation the veins cover a long distance, while when the angle is 90° the distance is very short. If the leaf is broad, this curving upwards of the ends of the veins does not affect the angle near the mid-rib but if the leaf is narrow the latter would be reduced. This may

TABLE XXII.

Venation in Type 9 Type 51.

		Venation of Parent	40°	45°	50°	55	60	65	70	75	80°	85°	90°	Total No. of Plants
Type 9	1912		1	27	26									54
Type 9	1913		1	9	16									26
Type 51	1912									5	23	20	3	51
Type 51	1913									14	18			32
F_1 Type 9 Type 51	1912					19	47	11						77
F_2 Type 9 Type 51	1911		19	12	147	30	200	21	89	29	42	12	7	608
Type 9 F_1 Type 9 Type 51	1911		38		173	2	55		1					269
Type 51 F_1 Type 9 Type 51	1911		1		22	5	51		37	4	49		38	207
F_3 Type 9 Type 51														
738	1912	50°	1	9	48	35	39	7	4					143
745	1912	50	1	17	58	40	22	1						139
736	1912	60	1	2	8	38	36	31	11					127
737	1912	60	9	17	81	27	17	9	1					160
740	1912	70			7	18	41	41	22					129
694	1912	75°				1	7	13	35	25	15	4		100
132	1912	80					1		10	31	39	21	14	116
167	1912	80 85				—				1	18	16	33	98
F_4 Type 9 Type 51														
738 19	1913	40	11	78	16									105
738 96	1913	50	22	10	4									66
738 58	1913	50			1	15	80	11						107
738 15	1913	55	1	7	38	22	27	5	1					101
738 76	1913	60		2	13	27	15	8	7					102
738 51	1913	70				1	85	44	4					134
694 1	1913	70					1	41	40	21				103
694 38	1913	70				—			10	45	32	20		107
694 23	1913	75							4	32	16	3		55
694–103	1913	80	—			1	8	15	26	27	20	2		99
694 10	1913	80	—					—	15	37	35	15		102

explain why there is a limiting effect without true correlation.

The study of the venation has yielded some most interesting results and has demonstrated very conclusively the existence of homozygotic combinations with values between those of the parents. Table XXII gives the results of the cross Type 9 Type 51. The F_1 is intermediate as usual, and the F_2 covers the combined range of the parents. In the F_3 only one culture, 167, appeared to be uniform, and this had a mean venation slightly greater than Type 51. The limits of variation were, however, very different in the various cultures, and two cultures in which these overlap very slightly, 738 and 694, were continued. From culture 738, with a range of 40° to 70° in the F_3, the plants with the lowest and highest angles were grown in the following year, as well as four others. In the F_4 generation two cultures 19 and 96 were uniform with an average venation of 50°, and a range of 40° to 55°, two others 58 and 81 were uniform with an average of 60°, while one culture 15 resembled the parent culture 738 in every respect. The behaviour of the other culture is not very clear; it may indicate another homozygotic combination at 55°. Thus two homozygotic combinations, representing 50° and 60° respectively, have been isolated, one of which is a replica of one of the parents, the other is new. The F_4 cultures of 694 do not give such definite information, but they indicate the occurrence of another homozygotic combination 65°-70°, and it is possible that 694-1 represents this.

The cross between Type 16 Type 35 (Table XXIII) gives very similar results to those described before. All the cultures (four) with a venation of 50° or 45° have bred true; one culture of which the parent plant had a venation of 60° has also bred true, and here again is the formation of a homozygotic combination intermediate between the two parents. Cultures 200 and 8 are possibly uniform with an average of 75°, again a *novum*. The other cultures are apparently heterozygotes splitting within different limits.

TABLE XXIII.

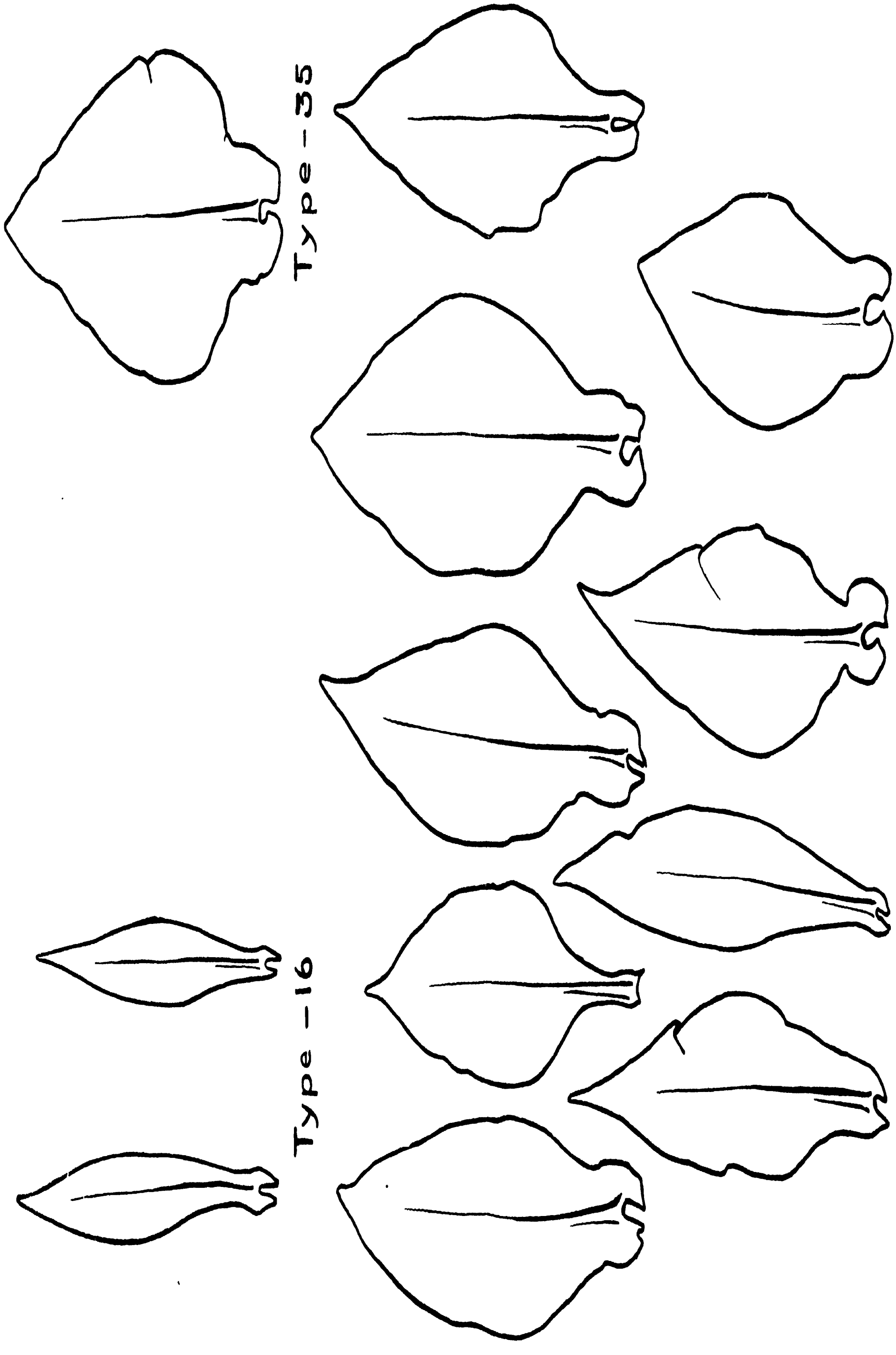
Venation in Type 16 × Type 35.

	Venation of Parent.	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	Total No of Plants.
Type 16 1912		—	13	49	11	-	—	—	—	—	—	—	73
Type 16 1913		—	—	22	10	1	—	—	—	—	—	—	33
Type 35 1912		—	-	—	—	—	—	3	10	52	9	—	74
Type 35 1913		—	—	—	—	-	—	—	13	19	2	—	34
F_1 Type 16 × Type 35 1912		—	-	-	—	7	28	-	—	—	—	—	35
F_2 Type 16 × Type 35 1912		—	6	32	29	58	43	41	25	20	7	1	262
F_3 Type 16 × Type 35													
27—1913	45°	-	17	78	14	1	—	—	-	—	—	—	110
202—1913	50°		22	73	9	3	—	—	-	—	—	—	107
190—1913	50°	—	21	67	21	—	—	—	--	—	—	—	109
231- 1913	50°	2	23	65	14	—		-	—	—	—	-	104
251—1913	55°	1	9	38	39	17	3	—	—	—	-	—	107
142—1913	55°	—	8	38	40	20	2	—	—	—	—	—	108
163—1913	60°	—	—			-	18	67	16	—	—	—	101
15—1913	70°	—	2	6	18	24	30	18	6	1	—	—	105
35—1913	75°	—	—	1	5	8	12	15	32	16	5	—	94
9—1913	80°	-				4	6	42	41	14	-	—	107
200—1913	80°	—	—	—	—	—	—	19	49	34	3	-	105
8—1913	85°	—	—		—	-	—	7	56	35	7	-	105

TABLE XXIV.

Venation in Type 23 × Type 38.

	Venation of the Parent	40°	50°	55°	60°	65°	70°	75°	80°	85°	90°	Total No of Plants.
Type 23 1912		—	—	—	—	-	33	38	2	—	—	73
Type 23 1913		-	—	—	—	—	12	14	—	—	—	26
Type 38 1912		—	—	—	7	28	23	3	—	—	—	61
Type 38 1913		-	—	—	7	22	11	—	—	—	—	40
F_1 Type 23 × Type 38 1913		—		—	—	1	13	35	—	—	—	49
F_2 Type 23 × Type 38 1912		—	—	—	4	10	46	34	5	1	—	100
F_3 Type 23 × Type 38												
213—1913			—	—	38	52	13	—	—	—	—	103
6- 1913	75°	-	—	-	-	—	24	69	11	—	—	104
155 1913		-	—	—	1	13	62	15	—	—	—	91
159—1913		—	—	-	12	32	38	23	—	—	—	105
104—1913	70°	—	—	—	—	1	55	39	50	1	—	146
111—1913		Like F_2 60°-80°										
204—1913		,, 60°-80°										



FORMS OF LEAVES IN F_2 TYPE 16 · TYPE 35

As the parents in the cross Type 23 × Type 38 (Table XXIV) are so similar as regards venation, no investigations on this character were contemplated. A few measurements were made, however, in the F_2 as some other characters had given curious results in this generation. The results obtained in this generation afforded very striking evidence of the accuracy of the method adopted, and so a few cultures were measured in the F_3. Type 23 has a range of 70° to 80°, Type 38 of 60° to 75°, both therefore overlap. The plants in the F_2 generation had a range of 60° to 85°, the combined range of the parents. In the F_3, cultures were found like both parents, i.e., Nos. 213 and 6, some like the F_2, Nos. 111 and 204 and others, which indicate the possibility of another homozygotic combination with an average of 70°.

7. THE LEAF SHAPE.

The most difficult characters to investigate are those connected with the shape of the leaf. The large number of forms, all slightly different, with apparently endless modifications of the individual parts, appear at first to defy analysis. A detailed study of the existing forms and their behaviour on hybridization shows that the number of characters is not so great as might be supposed, although the factors composing such characters are probably numerous. The form of a tobacco leaf can be expressed by a determination of the following points: (1) ratio length/breadth, (2) position of the greatest width, (3) amount of indentation at the apex, (4) amount of indentation at the base, (5) shape at the point of insertion, that is, whether auriculate or not. According to the evidence which has accumulated during these investigations all these characters are inherited quite independently of one another.

The influence of the ratio length/breadth on the shape of the leaf is obvious. The ratio depends on the two variable characters, length and breadth. Apart from environmental

influence, the width of the leaf is not dependent on the length. The Indian types of tobacco, with their great diversity of leaf shape, illustrate this point well. In countries with a high level of agriculture, economic considerations have eliminated all varieties except those possessing a certain type of leaf, a broad leaf with a large surface. In India, on the other hand, where the conditions of seed selection are primitive, and where thickness of leaf is desired for certain purposes, the cultivation of forms with very narrow leaves has persisted. Type 9 (Plates I and XVIII) is a very good example of a long narrow leaf and in Types 16 and 35 we have two leaves similar in length (average length, 42.9 cm. and 46.6 cm. respectively) with a very great difference in the

TABLE

Ratio $\frac{\text{Length}}{\text{Breadth}}$ in

				Ratio of Parent	1 4	1 5	1 6	1 7	1 8	1 9	2 0	2 1	2 2	2 3	2 4	2 5	2 6	2 7	2.8
Type 51			1912					1	7	21	11	3							
Type 51			1913						6	6	10	9	1						
F_1 Type 9	Type 51		1912										1	6	8	7	8	1	4
F_3 Type 9	Type 51																		
		167	1912				2	9	10	26	1,	21	8	1	1				—
		132	1912					2	7	21	29	26	14	5	2	2			—
		694	1912					1	4	18	19	20	13	10	5	3	1	1	—
		737	1912									1	3	3	6	7	10	10	12
		738	1912										1	4	6	10	10	15	14
		745	1912										1		3	4	2	7	9
		736	1912											1	4	7	5	12	13
		740	1912												2	3	6	18	20
F_4 Type 9	Type 51																		
		738– 81	1913	2 7											3	5	4	12	11
		738 15	1913	2 9											1	8	9	22	15
		738 58	1913	3 2														4	6
		738 76	1913	3 2											5	5	11	15	18
		738 19	1913	3 3													2	3	8
		738 96	1913	3 8														2	3
		694– 23	1913	1 9		2	1	8	19	18	4	1	2						
		694 1	1913	2 1							3	5	22	28	19	19	6	—	1
		694 103	1913	2 2		1	1	8	17	14	27	7	10	8	6	1	—	—	—
		694– 38	1913	2 2				2	16	21	27	27	12	2			1	—	—
		694 10	1913	2 2		1		1	8	14	26	32	15	5				—	—

width (average width 11.1 cm. and 29.2 cm. respectively). On Plate XIX are shown some of the leaves of the F_2 generation of this cross, drawn to scale.

All the evidence accumulated during these investigations tends to show that differences in width can be inherited quite independently of the length. The very great effect of fluctuating and temporary changes in environment on the size of the leaves makes a thorough study of the inheritance of the width or of the length difficult and necessitates a large number of measurements. Time has not permitted me to measure sufficient leaves per plant to make any very definite statements as regards the factors composing these characters. As regards

XXV.

Type 9 × Type 51.

2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	Total No. of Plants.
																					—	43
																						32
2	1	1																				42
																						93
																					—	108
																						95
14	7	12	9	4	9	4	2	2		2	1	2	1	1			1		1			124
14	16	9	10	6	5	4	4	3	4				1				1					137
9	12	14	16	13	8	5	9	7	4	3	5	2	1	2	1	1	2			—	2	142
12	17	14	6	9	4	7	3	4	4	1	1				1							125
24	12	18	9	10	4	2	1														-	129
13	17	17	9	6	3	4	2	2	2									—				110
10	9	5	5	1	3	1	3	1		—		—	—								—	93
6	18	9	9	9	12	11	4	5	4	3	1	1							—		—	102
7	17	4	5	6	2	—		1	1						1			—		—	—	98
16	7	5	14	10	10	8	6	1	1	3	2										—	99
4	8	7	13	7	6	7	1	3	2	1										—		64
—	—	—				—																55
—	—		—			—														—	—	103
—			—			—	—											—			—	100
—	—	—		—			—	—			—			—				—				108
—	—	—	—			—	—	—	—	—					—	—	—	—	—		—	102

TABLE

Ratio $\frac{\text{Length}}{\text{Breadth}}$ in

		Ratio of Parent.	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
Type 35	1912		6	21	18	6			—		—	—		—	—
Type 35	1913		—	11	18	8		—		—		—	—	—	—
Type 16	1912			—					—		—	—	—	—	—
Type 16	1913			—				—		—		—	—	—	—
F_1 Type 16 × Type 35	1913									1	3	6	20	19	7
F_2 Type 16 × Type 35	1912					2	4	16	37	42	61	42	68	45	36
F_3 Type 16	Type 35														
	9 – 1913	1 9					2	7	14	23	31	16	10	3	—
	8 – 1913	2 0						5	19	33	27	13	4	3	—
	200 1913	2 1			—	2	13	13	27	20	12	10	5	—	—
	231 – 1913	2 1						—	—		—	4	3	11	17
	202 – 1913	2 1		—						—				3	10
	35 1913	2 2				—		6	17	16	13	14	19	10	4
	15 1913	2 3							3	7	12	14	20	18	5
	163 – 1913	2 3							1		3	11	29	17	17
	251 1913	2 5			—					3	8	17	16	23	17
	142 1913	2 7							1	2	15	16	22	18	17
	190 1913											-	1	–	3
	27 1913										1	1	3	3	3

TABLE

Ratio $\frac{\text{Length}}{\text{Breadth}}$ in

		Ratio of Parent	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2 2	2.3	2.4	2.5	2.6
Type 23	1912								1		2	6	21	19	8
Type 23	1913						—		2	2	8	4	6	1	2
Type 38	1912				2	14	10	10	4	2				–	—
Type 38	1913				4	4	10	3	2	1		–		—	—
F_1 Type 23	Type 38 1913			1	3	9	22	8	4		1			—	—
F_2 Type 23	Type 38 1912		3	2	6	18	27	37	54	62	50	32	20	16	6
F_3 Type 23	Type 38														
	104 1913	1.6	4	14	30	31	12	6		-	—	—	—	—	—
	6 1913	1 9		2	11	13	26	16	13	11	2	2	1	1	—
	117 1913	2 0		2	7	12	11	12	9	12	6	1	—	—	—
	204 1913	2 0			3	5	17	22	16	17	11	6	2	1	—
	159 – 1913	2 0			—	4	12	23	12	24	11	8	4	4	2
	111 – 1913	2 1		3	2	11	6	21	20	13	14	3	1	2	1
	213 – 1913	2 2		2	2	15	18	23	19	12	7	3	1	1	—
	255 1913	2 4	—	—		3	10	16	25	18	19	5	3	4	—
	9 1913	—	1	11	16	26	18	18	4	1	3	1	—	—	—

XXVI.

Type 16 × Type 35.

2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	Total No of Plants
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		51
—	—	—	—	—	—	—	—	—	—	—			—	—	—	—		—	37
—	—	—	—	—	—	—	—	2		3	7	7	8	3	6	5	2	2	45
—	—	—	—	—	—	—	—	—	5	5	1	8	9	5	3	1	—	—	37
4	2	—	—	—	—	—					—	—	—	—	—	—	—	—	62
24	26	8	10	10	4	5	2	2	1	—		—	—	1	—	—	—	—	446
1	1	—	—	—	—	—	—							—		—		—	108
—	—	—	—		—	—	—		—				—		—	—	—	—	104
—	—	—		—	—	—	—	—	—			—	—	—	—	—	—		102
18	13	10	8	9	6	1	2	—	1	1	—	—	—		—	—			104
12	22	17	8	7	9	2	2		—	—	2		—	—	—	—	—	—	94
4	—	—	—	—						—	—			—	—	—	—	—	103
7	9	6	1	2	2	1	1	1	—	—		—	—			—	—		109
9	10	2	2	—	—	—	—		—	—	—	—	—	—	—	—			101
10	9	2	2	1		—	—	—	—	—	—		—	—	—	—		—	108
6	7	1	1	1	—	—	—	—	—	—			—	—		—	—		107
3	10	15	14	20	16	6	3	7	6		2		1	1			—	—	108
7	14	13	6	15	13	5	2	4	5	1	4	1	2	1	1	—	—	—	105

XXVII.

Type 23 × Type 38.

2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	Total No of Plants
4	2	—	—		—			—	—	—	—	—		—			—		63
—	—	—	—	—				—	—	—	—	—	—	—			—	—	25
—	—	—	—	—	—	—		—	—		—	—	—	—	—	—			42
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				24
—	—	—	—	—	—		—		—		—	—	—	—				—	48
2	—	—		—			—	—	—	—	—	—	—	—	—	—			335
—	—	—	—	—	—	—	—	—		—	—			—					97
—	—	—	—	—	—	—	—	—		—	—		—		—	—		—	98
—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	72
—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—		—	100
—	—	—			—	—	—	—	—				—	—		—		—	104
—	1	—	—	—	—	—	—	—	—	—		—	—	—	—	—	—	—	98
—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—	—	103
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	103
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	99

the environmental influences, however, both the breadth and the length appear to be similarly affected, and the ratio between the two is therefore less dependent on these influences. The ratio length/breadth has been studied in three crosses (see Tables XXV, XXVI, and XXVII). The results are very much the same as in other characters. In Table XXV the ratio from Type 9 is not given, as it will be evident from Table XVI that no two leaves are alike in this respect. In Table XXIV the most interesting culture is 694 which, although almost uniform in the F_3 generation, has shown further segregation in the following year.

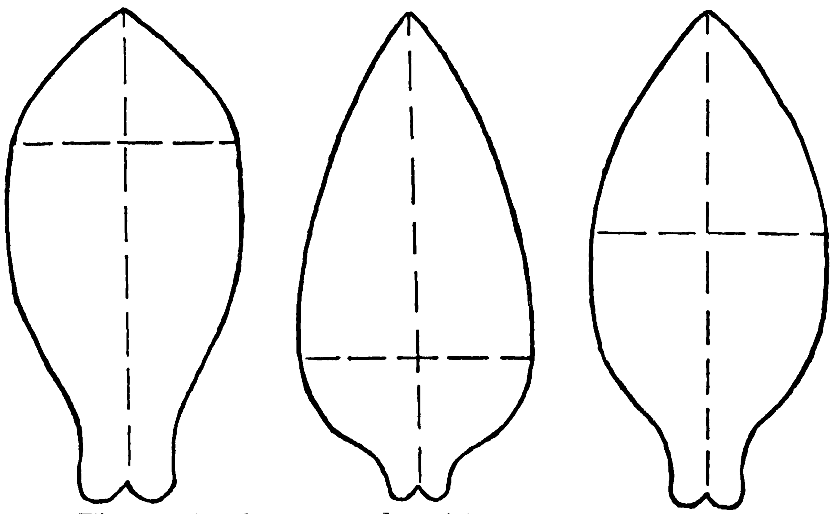
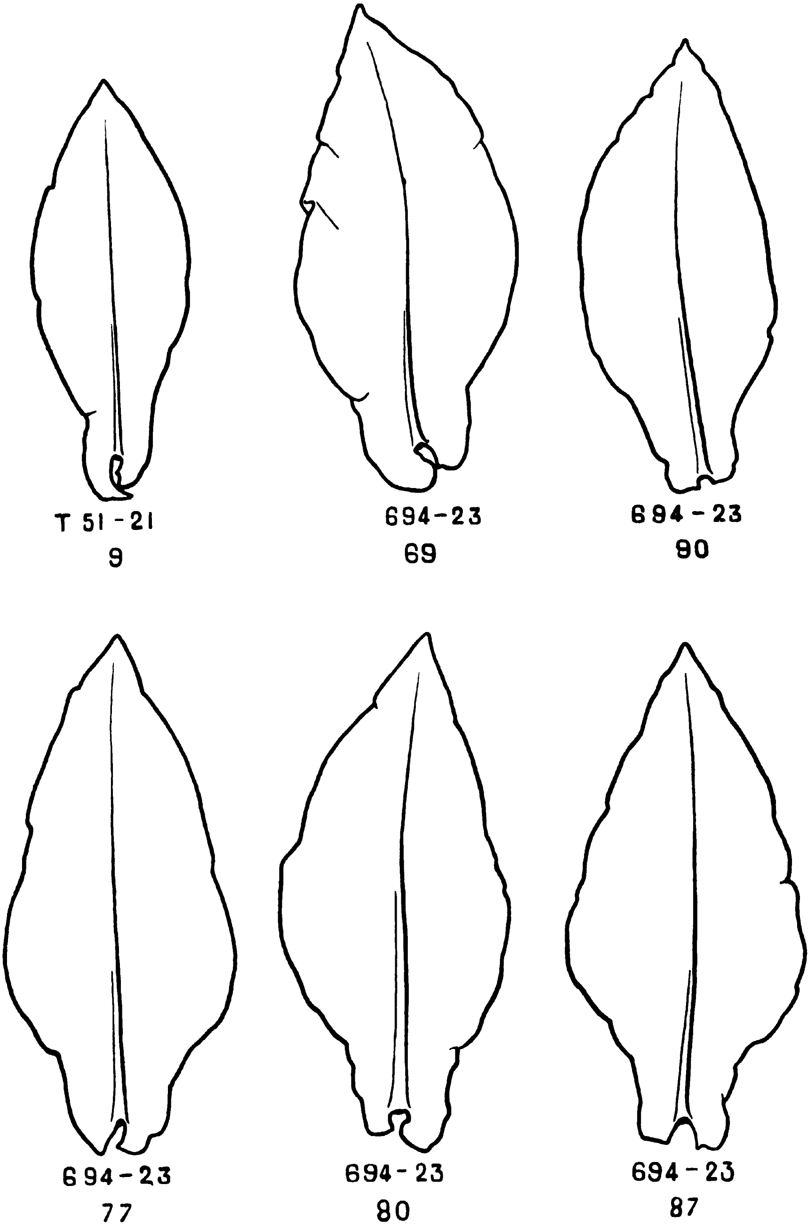


Fig. 1. Leaf shape and position of greatest width.

In cross Type 16 Type 35 where the length of the leaves is approximately the same, but the width very different, the ratios formed by a combination of the length of one with the width of the other are the same as the original ratios. The data of the F_3 generation clearly point to the action of several factors in producing the difference between the widths of the two leaves.

The position of the greatest width is a very important point in dealing with the leaf shape. The above diagram shows how the appearance of the leaf can be entirely altered by varying the position of this point.



LEAVES OF T 51 AND OF CULTURE 694 (F_4 T_9 T_{51})

In Type 51 the position of the greatest width has been determined for a large number of leaves, and is always half-way between the apex and the base. In Type 9 it is lower at a point two-fifths from the base of the leaf. Determinations of this point made in the F_4 generation on cultures derived from 694 showed that all were uniform in this respect and resembled Type 9 exactly, although in size and ratio length/breadth they were very like Type 51. On Plate XX some of these leaves are shown, contrasted with a leaf of Type 51. Apparently this character can be inherited quite independently of the ratio length/breadth and it is possible to combine in the same leaf the ratio length/breadth of one parent with the greatest width in the same position as in the other parent. Similarly, very distinct segregation as regards this character was observed in the cross Type 23 × Type 38. A large number of cultures have been measured with reference to this point, but as the number of tables is already great, the results will not be published until the fuller investigation of the factors concerned with the shape of the leaf is completed. The measurements were carried out by moving a steel measure at right angles up the leaf until it denoted the greatest width, when its position was marked by inserting a needle into the mid-rib. The distance between this point and the base of the leaf was then determined.

The ratio length/breadth and the position of the greatest width are sufficient to determine the general form of the leaf in all cases. If we further imagine pieces of varying size to be cut out at the apex and base of the leaf we are able to reproduce the leaves of all the existing types. If we postulate the existence of independent factors the effect of each of which is to cause a different indentation in the outline, all the facts which have been discovered during this investigation can be explained.

The most striking example is that given by the cross Type 23 × Type 38 (Table XXVIII). Both these forms have sessile leaves, but the amount of indentation near

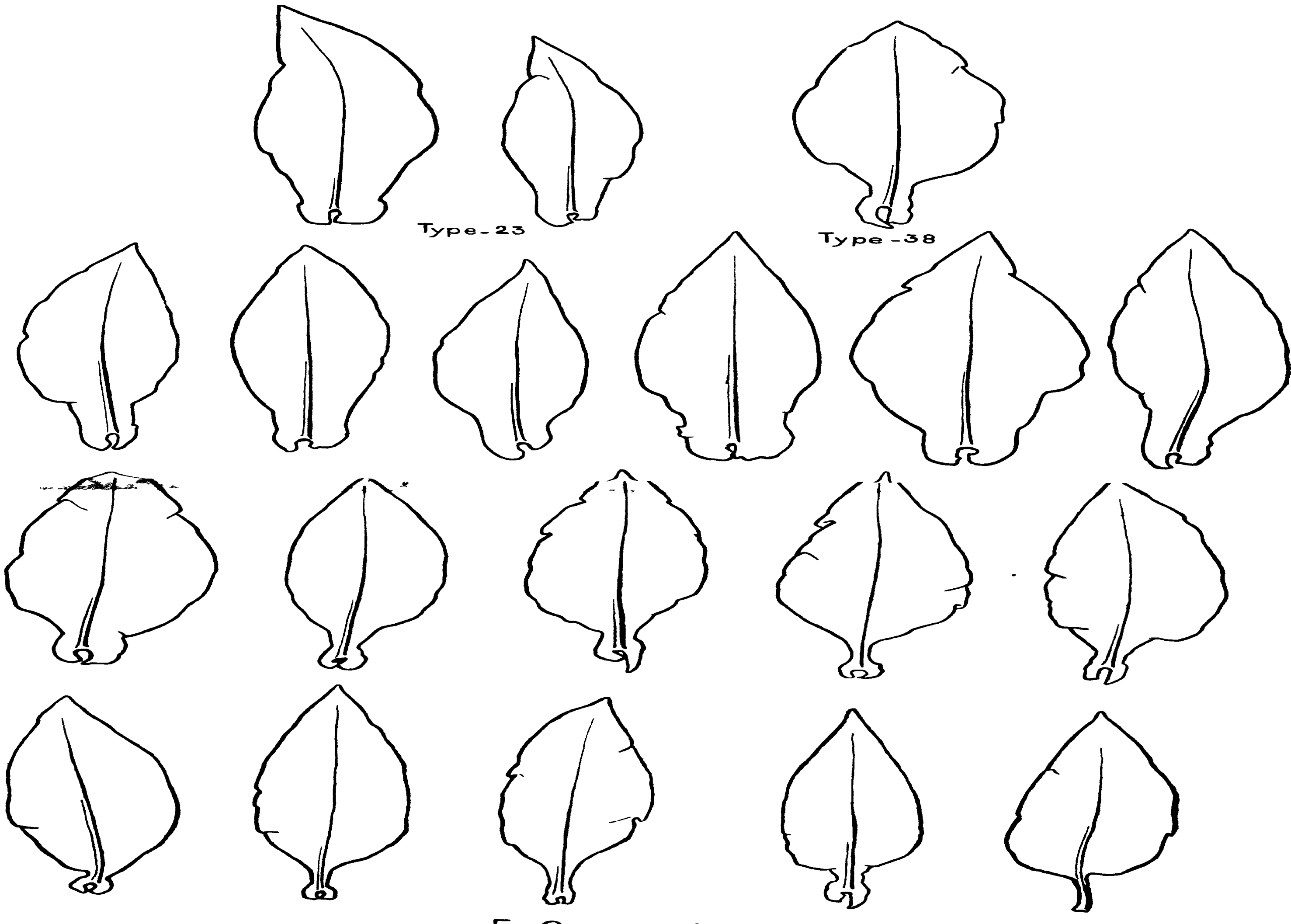
the base is different (see Plate XXI, in which both parents and typical leaves from the F_2 generation are shown). The measurements were obtained by measuring the lamina on either side of the mid-rib and obtaining the mean value. This is preferable to any measurement across the leaf as it eliminates the width of the mid-rib, which is probably an independently varying character. The outline of Type 23 is almost straight, while that of Type 38 is suddenly contracted. On hybridization, the F_1 has a bigger indentation than either parent. In the F_2, petiolate forms occur in which the amount of lamina on either side of the petiole is less than .3 cm. All stages between these and Type 23 were found. Nine cultures were carried on to the F_3. The petiolate forms, Nos. 117 and 213, bred true in the third generation. If the indentation in the parents be due to two different factors or combinations of factors, then the effect of their combined presence might be to reduce the lamina to a negligible amount. These forms possessing both factors would be homozygotic and breed true. Two cultures, Nos. 155 and 204, which in the F_2 possessed a small amount of lamina gave a progeny of petiolate and sessile forms which could be easily separated both by eye and by measurement into three distinct groups in the ratio 1 : 2 : 1. The actual numbers were as follows:—

Culture 159—petiolate 25, intermediate 52, sessile 27.

Culture 204—petiolate 24, intermediate 48, sessile 33.

The parent plants were probably homozygotic for one factor and heterozygotic for the other.

Three other cultures gave progeny in which a certain number of petiolate forms occurred, but these formed a series with the sessile forms, and the number of such plants was much less than a quarter of the whole. In two cultures, Nos. 104 and 111, no petiolate forms at all occurred. If the presence of both indentations is possible, the absence of both must also be possible. Some leaves with an outline showing even less indentation than Type 23 were found, but the range of variation of the latter was, in 1913, so great that



F_2 Generation.

FORMS OF LEAVES IN F_2 TYPE 23 × TYPE 38

this could not be confirmed by direct measurement. These cultures were very luxuriant and over-grew their normal limits. The question is complicated by the fact that the indentation of Type 38 is sudden and short, while it is gradual in Type 23. Indications of a segregation in this direction were also observed. These results indicate that the apparently stalked varieties of tobacco are not really petiolate, but sessile. This explains the alate nature of the petiole and the fact that in many such types the upper leaves are sessile, the lower petiolate.

Further evidence on this point was obtained from the other two crosses. Many cases in which the form of the lower part of the leaf varied, but the indentation factors did not differ so widely as in Type 23 and Type 38, were observed in the F_4 generation of the cross Type 9 × Type 51. No petiolate forms occurred, showing that the combined effect of the indentation factors was not great enough to remove all the lamina. Different ranges were shown by different cultures.

Observations in the field together with a comparison of Tables XXV, XXVI and XXVII, show that these indentation factors are inherited quite independently of the leaf ratio and also independently of the width of the leaf. Environmental influences would, however, by influencing the vigour of the plant, affect both alike.

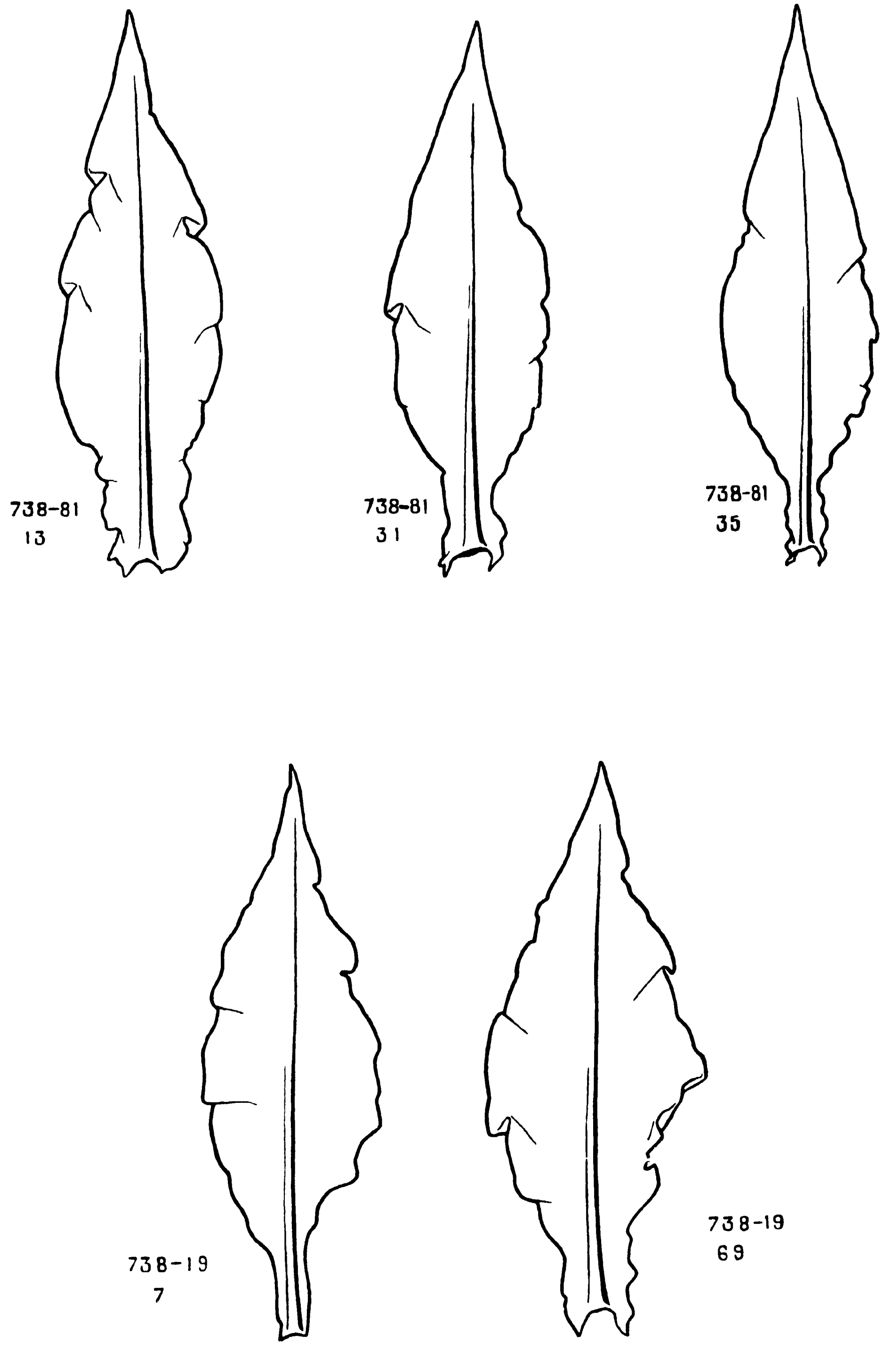
Plate XXII shows three leaves selected from culture 738-81, in which both width and length are the same but the amount of indentation at the base varies. On the same Plate are shown two leaves of 738-19, in which the length is the same, but the width and the form of the base vary. In some cultures the configuration of the base was uniform, such as 694-1. Plate XIX gives a very good indication of the range obtained as regards this character in the cross Type 16 × Type 35. The F_3 cultures showed very different limits of variability. In one case, culture 9, there was apparently only one heterozygotic factor, a separation by eye gave twenty-five plants with a similarly broad base in 108 plants.

A similar explanation to the series of independent intensifica-tion factors appears to hold good in the case of the leaf apex. A curious feature of the leaves in some of the Indian tobaccos is a sudden constriction of the lamina near the apex of the leaf, which gives the appearance of a prolongation of the surface into a long slender tip; in others the tip is short. Good examples of both these cases are seen in the F_2 generation of Type 16 × Type 35. (Plate XIX). At first sight it would appear as if this sudden constriction were absent in both parents but indications of it can be detected in the apex of Type 16, although the narrowness of the leaf has diminished its effect. Evidence as to the independence as regards inheritance of the factors concerned in the configuration of the apex is given in this Plate. Other examples are shown on Plate XXIII. In 738-81, Nos. 14 and 60, are shown two leaves with similar apices but dissimilar widths, in 738-15, Nos. 38 and 96, are shown two leaves with the same width, but dissimilar apices, while 738-19, Nos. 68, 47 and 23, show the two extreme forms of apex found in that culture with an intermediate form. All these drawings are to scale.

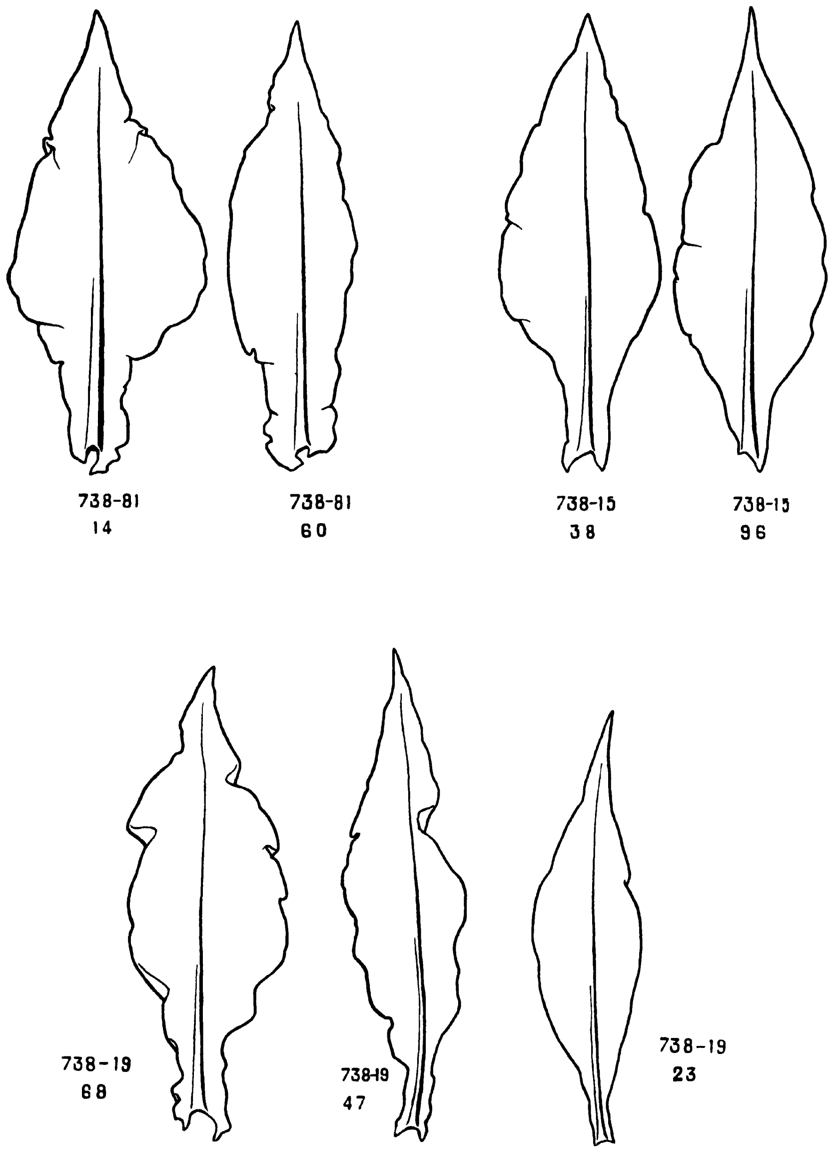
In three F_3 cultures of the cross Type 16 × Type 35, the leaves could be divided by eye as regards the configuration of the apex, into three different groups giving a ratio 1 : 2 : 1. This shows that the plant was heterozygotic as regards one apical factor only. Culture No. 9 gave 29 leaves with broad apices; 50 intermediate; 30 with pointed apices. Culture No. 35 gave 30 : 50 : 24. Culture 163 bred true as regards the apex. These three cultures are illustrated in Plate XXIV.

No information is as yet available as regards the inheritance of the presence and shape of auricles at the base of the leaf.

It is hoped to publish a further paper on the factors concerned in the leaf shape when the study of the pressed leaves has been completed, but enough evidence has been given in this section to show that the form of the leaf can be expressed by a knowledge of the ratio length/breadth, the position of greatest

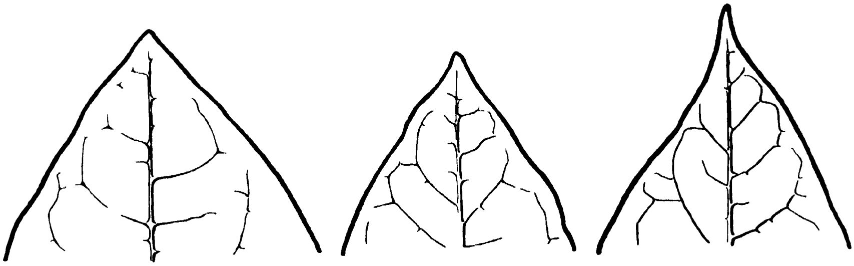


VARIOUS FORMS OF LEAVES IN CULTURE 738 (F_4 T_9 T_{51})

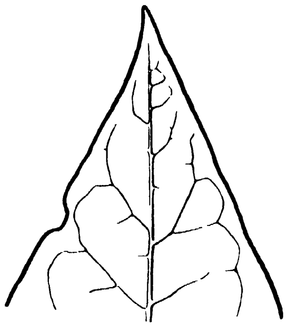


INDEPENDENCE OF WIDTH AND APEX

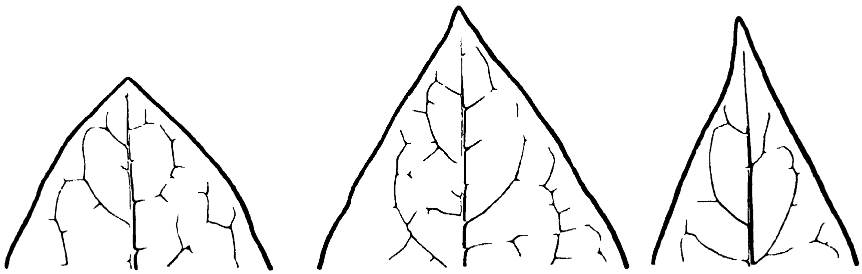
16 × 35 – 35



16 × 35 – 163



16 × 35 – 9



DIFFERENT FORMS OF APEX

width, and the amount of indentation at the apex and base. All these characters vary independently of one another and can be inherited separately, and their mode of inheritance can be explained by the existence of independent interchangeable factors.

8. CHARACTER OF THE SURFACE AND THE MARGIN OF THE LEAF.

These characters are very difficult to investigate. In the first place, the nature of the irregularities in the surface may be different; in the second place, the various stages and combinations are very difficult to distinguish by eye; in the third place, even the so-called flat leaves have a certain amount of undulation at the base. From a study of the various Indian types, the following conditions appear to be the most frequent—large undulations of the whole leaf as in Type 9, large undulations confined to the base only, a general puckering of the surface between the veins and a small undulation or "frilling" of the edge. This frilling of the edge occurs in Type 51, but is best shown by the photograph of a plant which arose from the cross Type 9 × Type 51, namely, No. 694-23 in Plate XVI.

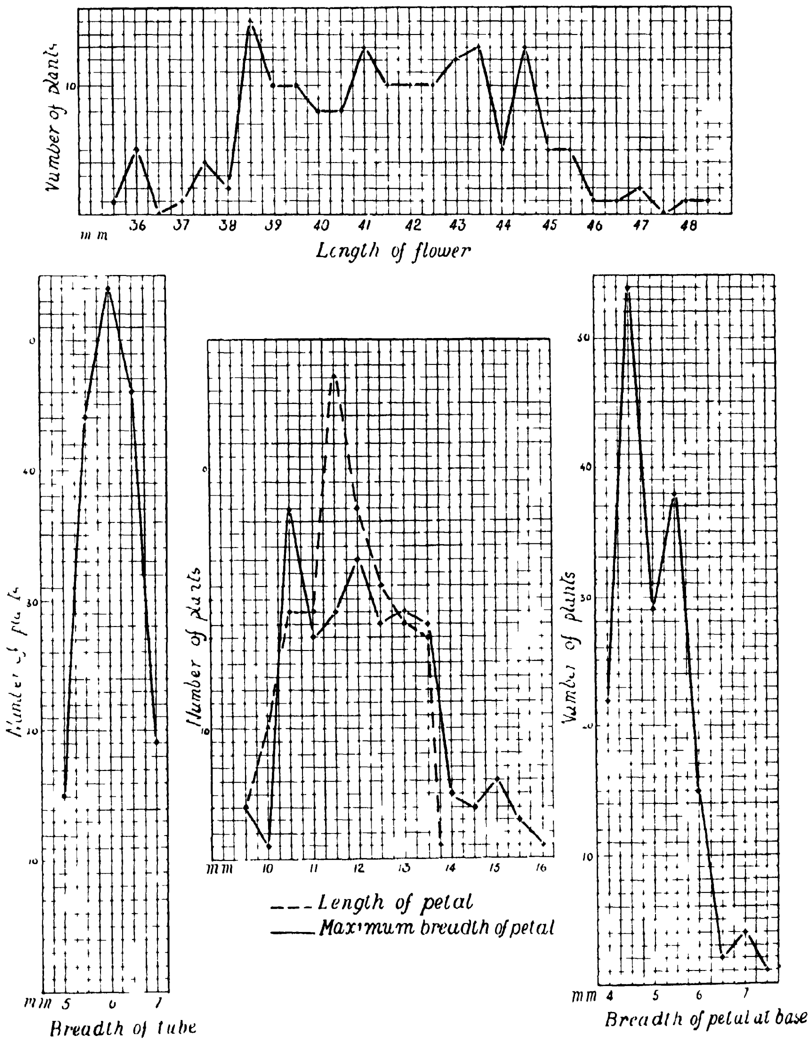
The investigations on this point have been confined to the cross Type 9 × Type 51. Type 9 has a leaf which is very undulate all over, while in Type 51 the edge is frilled but the surface is flat except at the extreme base, where an occasional slight undulation may occur. Taking the leaf surface only, it was found that the F_1 was intermediate and that the F_2 showed a series of forms intermediate between both parents, with a slight intensification, a few plants being more undulate than Type 9. Two hundred and fifty plants were examined by two observers. It was found possible to distinguish seventeen plants like Type 9, and three slightly more undulate. Fifty-seven plants were found with a slight undulation at the base or quite flat. These two classes could not be sub-divided. The

remainder could be classified as follows :—base slightly undulate, slightly undulate all over, undulate at the base only, undulate all over, very undulate all over, a little less undulate than Type 9,—showing that in all probability the undulation of the base is determined by a different factor to that of the general surface of the leaf. The numbers obtained indicate the existence of two factors and a ratio of 15 : 1, namely, 17 + 3 plants like Type 9 in 250 plants gives a ratio 11.5 : 1. It is, however, possible that the occasional undulation noticed at the base of Type 51 owes its existence to a third factor and that the plants that were even more undulate than Type 9 represent the combination of the factors involved in Type 9 plus this factor. The ratio 247 : 3 makes this appear possible. The seventeen plants like Type 9 would consist of the homozygotic combination Type 9, the heterozygotic intermediate between Type 9 and Type 9 intensified by the factor from Type 51. In a three factor combination the ratio of these to the total number of plants would be 3 : 64, i.e., there should be twelve plants, not seventeen. The number of plants examined is, however, two few to enable any definite conclusion to be drawn.

The "frilling" of the edge appears to be inherited independently of the surface undulations. This character cannot be observed when the general undulations of the leaf are great. In the present case this character was observed on fifty-seven plants. Of these, fifteen had no frilling at the edge, the others were frilled to a varying degree. This gives a ratio 42 : 15, or 2.8 : 1, so that here we are dealing with a simple factor. Some of these plants with flat leaves and frilled margins were carried on in the F_3 generation, and the following results were obtained :—

Culture 694—105 plants, 78 with frilled margins, 27 with flat margins.

Culture 167—99 plants, 73 with frilled magrins, 26 with flat margins.



COROLLA MEASUREMENTS F_2 TYPE 9 × TYPE 51

9. COROLLA.

As regards the corolla the following measurements were made on both parents, the F_1 and F_2 generations in the cross Type 9 × Type 51—length of the flower, length of the individual petal, maximum breadth of the petal, basal breadth of the petal, breadth of the corolla tube and breadth of the funnel. The results observed were similar to those obtained in the leaf characters. The intermediate nature of the F_1 was perfect even to the method of pollination. The F_2 generation gave a series covering the limits of both parents. The full data are not given here as they present no new features, but a graphic representation is given in Plate XXV. Want of time made further measurements in the F_3 and F_4 generations impossible.

The difference in the colour of the corolla in this case was probably due to two factors. The F_2 generation could be divided into more than three groups, and those classified as white formed one quarter of the whole, forty-five plants out of 117. The large number of gradations obtained in the F_2 generations indicate that this is probably not a simple 3 : 1 ratio, but that some of the palest pink combinations were indistinguishable from white.

V. CONCLUSIONS.

The results obtained in these investigations may be briefly summed up as follows :—

1. In any statistical investigation on the mode of inheritance, the uniformity of the environment in which each set of cultures is grown is exceedingly important. Comparisons should not be drawn between cultures unless they are grown close to one another with full precautions as to uniformity in environment. By careful attention to cultural details it is possible to reduce greatly the effect of environmental fluctuations. The importance of using in such investigations only normal, well grown plants cannot be over-estimated.

2. Parthenogenesis in *N. tabacum*, under the conditions obtaining in hybridization work at Pusa, is negligible.

3. In all characters except height, the F_1 generation is intermediate between the parents. In the case of the height, different results were obtained in different crosses. This may be due to added vigour in the hybrid plants. It is suggested that the differences in the increase produced by this may depend on differences in the number of dissimilar factors in the parents.

4. In all cases the limits of variation in the F_2 generation have been as great as those of both parents combined or have exceeded these in both directions. In some cases, where the parents and the F_1 generation were all alike, the variation in the F_2 was very great. This can readily be explained by the hypothesis that most of the factors possessed by the parents are different.

5. Selected variates of the F_2 generation gave cultures which differed in their range of variation from one another, and

often from the parents—the range of variation diminishing with further selection. Certain cultures showed so small a range of variation as to appear uniform; some of these resembled the parent forms, some were new.

6. Observations on the time of flowering during four generations resulted in the isolation of a culture flowering slightly earlier than one parent, and others flowering much later, together with some in which the range of variation was great.

7. It has been shown that although the heights of tobacco plants may only differ slightly, nevertheless the factors on which such heights depend may be almost all different. In one cross, a new form (probably uniform) much shorter than the shorter parent, has been isolated; in another cross, forms resembling both parents were obtained. If there is a basal condition of height common to all tobacco plants it must be small.

8. The number of leaves per plant does not depend on the height of the plant and is practically independent of the environment. The inheritance of this character can be explained by a basal condition (of not more than nineteen leaves) common to all types of *N. tabacum*, combined with independent factors which can add to this number. These factors are probably different in magnitude, that is, they represent an addition of different numbers of leaves.

9. Distinct segregation has been observed as regards the arrangement of the leaves on the stem. The arrangement with internodes of equal length invariably breeds true.

10. The length of the decurrent portion of the lamina is probably due to the existence of several factors. Hybridization between plants whose leaves are equally decurrent has produced forms with nondecurrent leaves. The differences in length due to the various factors may be very small.

11. The most suitable leaves for measurements of the lamina are those in the centre of the plant.

12. The venation of the leaves is one of the most constant characters of the plant. On hybridization, the parent forms

have been re-isolated in the F_3 and F_4 generations and also constant forms with intermediate venation. Many of the factors involved have a very small external effect.

13. The shape of the leaf in *N. tabacum* may be defined by the ratio length breadth, position of the greatest width, amount of indentation of the apex, amount of indentation of the base, nature of the insertion, whether auriculate or not. All these characters can be inherited independently of one another. By the hybridization of two forms, in which the indentation factors of the base differ, "petiolate" forms which at once breed true, are produced by the combined action of the factors. All "petiolate" leaves in this species are probably sessile leaves with deep indentations.

14. The irregularities of the surface of the leaves depend probably on several factors. The undulation of the margin in the particular case investigated proved to be due to a single factor which is inherited independently of the factors concerned in the surface of the leaf.

15. Measurements of the size of the corolla show that this organ resembles the leaves in its mode of inheritance.

From the above results the following general conclusions may be drawn: The data obtained by a study of the characters of *N. tabacum* show that there is no inherent difference in the mode of inheritance of ordinary qualitative characters (such as the colour of the corolla) and of those characters connected with the size of the organs which are subject to fluctuating variability. All the results obtained can be explained by the Mendelian assumption of segregation of characters, combined with the hypothesis that in connection with each character a large number of factors exist, each of which can be inherited independently. This conclusion is supported by the great range of variation in the F_2 generation, the formation of extreme forms in this generation far outside the limits of the parents, the differ-

ences and diminution in the range of variation in the F_3 cultures raised from different variates of the F_2 generation and by the isolation in the F_3 and succeeding generations of forms like the parents and also of intermediate forms which breed true. This isolation of new forms can easily be explained by a rearrangement of the factors.

Pusa,
April 22nd, 1913.

APPENDIX.

DESCRIPTION OF THE TYPES USED IN HYBRIDIZATION.

Type II. Plants late, tall; height 150 cm.; lower internodes short, upper ones long; most of the large leaves borne near the ground; no large leaves in the upper two-thirds of the plant. *Leaves* petiolate, petiole is slightly alate in the lower leaves, more so in the upper ones; the wings are decurrent down the main stem for about 2.5 cm.; leaves inserted at an angle of 90° and bend downwards from the top of the petiole, asymmetric; shape varies from ovate to lanceolate according to the position on the stem; venation acute-angled, secondary veins arising at an angle of about 60°; apex acute; margin entire or slightly undulate; colour blue-green; texture thick; average length of petiole 6 cm.; average length of lamina 49 cm.; ratio length breadth 2.5. *Inflorescence leaves* petiolate, petiole not alate, inserted at an angle of 60° 90°, lanceolate; apex acuminate; margin generally entire, sometime undulate. *Inflorescence* raised, side branches borne at regular distances up the stem, parallel to but not as long as the main axis. *Flowers* a deep pink colour which does not fade much; length 45 mm. *Calyx* slightly globular and inflated, about one-third the length of the corolla; teeth moderately long and acute. *Corolla* with an orifice 8 mm. in diameter, a broad tube, and the transition between the tube and the dilated portion abrupt; limb not very deeply divided with folds at the junction of the lobes; lobes very rounded at the base; apical points short and somewhat reflexed. *Capsule* much longer than the persistent calyx, conical; apex blunt.

The anthers burst as the flower expands, not in the bud, and at this period are above the stigma. In the fully open flower the burst anthers are about 5 mm. above the stigma and project well beyond the orifice of the corolla.

Type III. Plants very late, tall; height 150 cm.; lower internodes very short, upper internodes long; some of the lowest leaves lie on the ground, the others are borne at long intervals up the stem. *Leaves* petiolate with alate petioles, the wings of the petiole expand on reaching the stem and are amplexicaul and decurrent for 5 cm.; leaves inserted at an angle of about 60° and bend downwards; shape ovate to cordate; secondary veins arise at an angle of more than 60°; apex acute; margin undulate; leaf undulate; surface puckered; texture thick; colour dark blue green; average length of petiole 5 cm.; average length of leaf 41 cm.; ratio length breadth 1.5. *Inflorescence leaves* petiolate with very short alate petioles, inserted at an angle of 90°, ovate; apex acuminate; leaf undulate and surface generally puckered. *Inflorescence* with few flowers and with very spreading sideshoots which arise at regular intervals on the upper half of the main stem. The side branches bear very few flowers. *Flowers* pink, the colour easily fades; length 42 mm. *Calyx* globular and inflated, less than one third the length of the corolla; teeth moderately long and acute. *Corolla* with a broad tube and short dilatation, diameter of orifice 8 mm.; the transition between the tube and the expanded portion abrupt; limb not very deeply divided; lobes much rounded, pointed but with no distinct apical points. *Capsule* much shorter than the persistent calyx, conical; apex blunt.

The anthers burst as the flower expands, not in the bud, and occupy a position above the stigma. In the fully open flower, the burst anthers are about 5 mm. above the stigma and project much beyond the orifice of the corolla.

Type IX. Plants early, dwarf; height 104 cm.; lower internodes very short, causing nearly all the large leaves to lie on

the ground. *Leaves* sessile, inserted at an angle of 90°, slightly amplexicaul, lanceolate, lamina much narrowed towards the base, venation acute-angled, secondary veins arising at an angle of 50°; apex acuminate, median leaves prolonged into very long thin points; margin and lamina with deep undulations, lamina raised between the secondary veins, giving the appearance of folds or ridges; colour dark green; texture very thick; average length 56 cm. *Inflorescence* leaves sessile, inserted at an angle of 90° and droop downwards from the base, linear; apex acuminate; the whole leaf is very sinuate and sometimes even twisted. *Inflorescence* conspicuous and raised above the leaves, with numerous side shoots which are almost as long as the mai i axis and not very spreading. *Flowers* a very pale pink colour, short (36 mm.). *Calyx* tubular with long and acute teeth, more than half as long as the corolla. *Corolla* with a wide orifice (11 mm.), and a broad tube, the transition between the tube and the dilated portion somewhat gradual; limb divided to about half its depth; lobes rounded at the base; apical points short, straight and only slightly reflexed. *Capsule* cylindrical with a somewhat blunt apex; persistent calyx longer than the capsule.

In the unopened bud all the stamens are below the stigma. The anthers burst just as the flower opens while they are still below the stigma or at the most touch the underside with their apices. In the open flowers the stigma is much above the burst anthers and all project beyond the orifice of the corolla. In some of the buds the stigma is visible between the still closed lobes of the corolla.

Type XVI. Plants somewhat early; height 141 cm.; habit very open, internodes long, only two or three leaves lie on the ground. *Leaves* sessile, inserted at an angle of 90° and droop downwards from near the base, amplexicaul, sometimes slightly auriculate, decurrent, lanceolate, lamina slightly narrowed at the base; secondary veins arise at an angle of 50°: apex acuminate; margin entire; lamina flat except

for occasional slight undulations at the base of some of the leaves; colour very light green; texture medium; average length 46 cm.; ratio length/breadth 4.1 *Inflorescence leaves* similar to the lower leaves but much narrower, in some cases linear, and the undulations at the base are more marked. *Inflorescence* raised with long side branches which are somewhat parallel to and not as long as the main axis. *Flowers* few in number, pale pink; length 50 mm. *Calyx* tubular, somewhat inflated, about one-third the length of the corolla; teeth long and acute. *Corolla* slender, with an orifice 8 mm. in diameter; tube slender, the transition between the tube and the dilated portion slightly abrupt; limb divided to about half its depth; lobes rounded at the base; apices very pointed but no apical point. *Capsule* shorter than the persistent calyx, conical; apex pointed.

The anthers burst in the bud when level with the stigma. In the fully open flowers the empty anthers are just above the stigma and generally slightly project from the orifice of the corolla.

Type XXIII. Plants somewhat early; height 136 cm.; leaves few, lower internodes short, causing some of the leaves to be borne very near the ground, upper internodes long; inflorescence raised in a few long slender branches. *Leaves* sessile, inserted at an angle of 90° and bend downwards from near the base, amplexicaul, very slightly decurrent, elliptical, lamina slightly narrowed towards the base; secondary veins arise at an angle of 75°; apex acuminate; margin and base of leaf undulate; surface puckered; leaf not fully expanded but folded on the midrib; colour yellowish green; texture thick; average length 46 cm.; ratio length breadth 2.3. *Inflorescence leaves* similar to the lower leaves but narrower. *Inflorescence* raised on a few, long, spreading branches. *Flowers* few, pale pink; length 45 mm. *Calyx* tubular, somewhat inflated, a little less than half the length of the corolla; teeth moderately long and acute. *Corolla* with an orifice 8 mm. in diameter; tube broad,

the transition between the tube and the dilated portion somewhat abrupt ; limb divided to about half its depth ; lobes not rounded at the base ; apical points long and sometimes oblique. *Capsule* shorter than the persistent calyx, cylindrical ; apex blunt.

The anthers burst in the bud or as the flower is expanding and are then just above the stigma. In the fully open flower the empty anthers and the stigma maintain their relative positions and are level with the orifice of the corolla.

Type XXXVI. Plants somewhat early, short with exceedingly broad leaves ; height 106 cm. ; internodes very short, several leaves lie on the ground. *Leaves* sessile, inserted at an angle of 60° afterwards becoming horizontal, auriculate, amplexicaul, decurrent for about 1 cm., the decurrent portion of the lamina being very broad, elliptical ; secondary veins arise at an angle of 80° ; apex acute ; margin with slight regular undulations ; surface puckered ; colour blue-green ; texture thin ; average length of leaf 48 cm. ; ratio length breadth 1.6. *Inflorescence leaves* resemble the lower leaves in every particular but are smaller. *Inflorescence* inconspicuous, scarcely raised and much hidden by the large leaves ; side branches few, short and spreading. *Flowers* large, a very deep pink colour which does not fade ; length 50 mm. *Calyx* globular, inflated, about one-third the length of the corolla ; teeth short and obtuse. *Corolla* with an exceedingly broad tube ; diameter of the orifice about 10 mm. ; transition between the tube and the dilated portion abrupt ; limb entire with slight indentations between the lobes which have no apical points. *Capsule* equal in length to persistent calyx, broad, conical ; apex blunt.

The anthers and stigma are at the same level both in the expanding bud and in the fully open flower. The anthers burst just as the flower opens. Both anthers and stigma remain just below the level of the corolla orifice.

Type XXXVIII. Plants somewhat late and tall ; height 134 cm. ; internodes short, giving the plant a somewhat bushy appearance, several large leaves near the ground. *Leaves*

sessile, inserted at an angle of 60°, the upper portions of the leaves tend to become horizontal, amplexicaul, auriculate, decurrent, elliptical, lamina only narrowed just at the base; secondary veins arise at an angle of 70°; apex acute; margin with regular, very small undulations; surface slightly puckered; colour light green; texture thin; average length 47 cm.; ratio length breadth 1.8 *Inflorescence leaves* similar to the lower leaves. *Inflorescence* not conspicuous and not much raised. Flowers very pale pink in colour; length 45 mm. *Calyx* globular, inflated, about one-quarter the length of the corolla; teeth moderately long and acute. *Corolla* with a wide orifice (diameter 10 mm.), tube exceedingly broad and the dilated portion very short, the transition between the latter and the tube very abrupt (the shape of the corolla in this type is unique among the Indian tobaccos): limb quite entire. *Capsule* longer than the persistent calyx, conical: apex pointed.

The anthers do not burst in the bud but as the corolla expands, when the anthers are well above the stigma. In the fully open flower the burst anthers are about 5 mm. above the stigma and project from the orifice of the corolla.

Type LI. Plants somewhat late, very tall; height 178 cm.; internodes long, leaves borne at regular intervals up the stem, none on the ground; inflorescence not very conspicuous. Leaves sessile, inserted at an angle of 60°, slightly amplexicaul and auriculate, decurrent for 5 cm. or more, the decurrent portion broad; shape elliptical, lamina somewhat narrowed in the basal third of the leaf; secondary veins arise at an angle of about 80°; apex acute; margin very slightly undulate and recurved; surface slightly puffy or puckered; colour dark blue-green; texture very thin; average length 43 cm.; ratio length/breadth 1.8. *Inflorescence leaves* similar to the lower leaves, but with more acute apices. *Inflorescence* with few flowers; the side branches which are borne at the top of the stem are few in number and almost level with the main axis and parallel to it. *Flowers* very pale pink in colour, fading to

white ; length about 45 mm. *Calyx* globular, inflated, less than one-third the length of the corolla ; teeth short and acute. *Corolla* with a wide orifice 11 mm. in diameter and a very broad tube, the transition between the tube and the dilated portion very abrupt ; limb entire but indented and somewhat folded at the junctions of the lobes ; apical points very short. *Capsule* longer than the persistent calyx, conical ; apex pointed.

In the bud before the corolla expands the anthers are found just above the stigma and burst while in this position before the bud opens. In the fully open flower the burst anthers are about 5 mm. above the stigma and project from the orifice of the corolla.

This type has an exceedingly good texture, the leaves are much thinner than in the ordinary Indian tobaccos. It has the great disadvantage, however, that the leaves are much exposed to the wind and do not protect each other as in the more bushy types. For this reason they are often badly torn before they ripen.

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

RED ROT OF SUGARCANE

BY

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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The most serious disease to which sugarcane is subject in India is undoubtedly that known as "red rot," caused by the fungus *Colletotrichum falcatum* Went. In 1906, a preliminary account of its characters and the damage caused by it in Bengal, especially that part which is now Bihar, was published in these Memoirs.[1] The most important conclusions there come to were that the disease ordinarily results in Northern India from the use of infected canes as "seed" and that the most hopeful method of checking it was by careful selection of the setts at the time of planting.

In a subsequent paper[2] the advantage of this practice was emphasised, some striking illustrations being given. Further experience has only increased the evidence of the value of sett selection which, while not an infallible preventive, is ordinarily instrumental in greatly diminishing the incidence of the disease. It is worth considering this evidence in detail, since infection from diseased seed has recently been denied by American[3] and West Indian[4] writers.

[1] Butler, E. J. Fungus diseases of sugarcane in Bengal. Mem. Dept. of Agric. in India Bot. Ser. I, No. 3, 1906.

[2] *Ib.* The selection of sugarcane cuttings. Agric. Journ. of India, II, 1907, p. 193

[3] Edgerton, C. W. The red rot of sugarcane. Louisiana Agric. Expt. Stn. Bull. 133, 1911, p. 11.

[4] Red rot fungus and the sugarcane in the West Indies. Agricultural News, XII, Nos. 286-7-8, 1913.

SETT SELECTION.

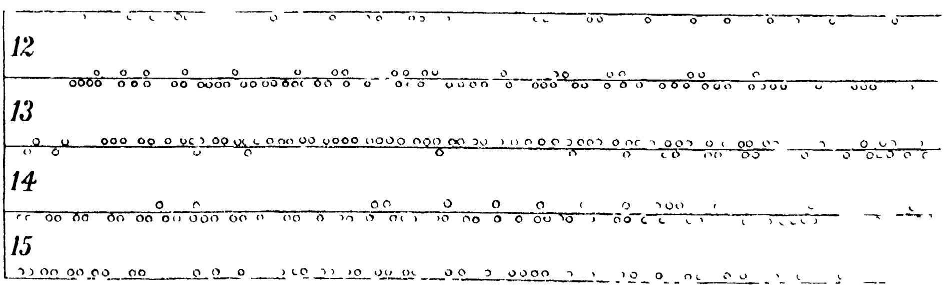
In 1906, alternate rows of diseased and healthy setts of a Madras cane, known as Yerra, were planted at Pusa, on February 26th-27th. Prior to planting, the presence of *Colletotrichum falcatum* had been determined in a large proportion of the canes from which the diseased setts were cut. By the 6th week after planting a decided difference was noticed in the two lots of seedlings. Those from diseased canes were withering in considerable numbers. *Colletotrichum falcatum* was found, in practically every case examined, in the young shoots, usually in the mycelial condition but in several instances producing spores at the basal nodes. In this, as in other cases where it was necessary to determine the identity of the organisms present in diseased cane, considerable use was made of the method of incubating aseptically removed slabs, described on page 8 of the Memoir above referred to. White ants, which are a frequent cause of injury to cane seedlings and which complicate the diagnosis in many cases of fungal attack, were absent from this particular crop, probably because the field in which it was grown was liable to flooding. *Sphæronema adiposum*, a fungus which is able to attack cut setts but not uninjured cane, and a parasite belonging to the genus *Cephalosporium*, which will be described in a subsequent paper, were found in a few cases.

The field in which this crop was grown had not been under cane in recent years and no other cane had been grown the previous year within about half a mile. There was, therefore, no reasonable risk of external infection and certainly no possibility of such an infection as would lead to the death of many plants in the trenches planted with setts from diseased cane, while the alternate, strictly comparable, trenches with healthy seed escaped. The photograph reproduced as Plate XII in the Agricultural Journal of India for 1907, shows the appearance of this plot on May 17th, and could hardly be more decisive. Under the microscope it was easy to trace the fungus from the setts up into the young shoots, and throughout April and May continued infection of the young shoots from their point of

origin occurred. On May 30th the number of sound shoots was counted in the trenches numbered 3 to 18, of which the odd numbers were from healthy seed and the even from diseased, the result being 679 and 117 respectively. The crop was lost by a severe flood in August, so that the final result cannot be given.

In 1907, the experiment was repeated in a field not subject to flooding, ten trenches being sown on March 7th with the varieties Striped Mauritius and Red Mauritius. By the end of April the results were as striking as in the previous year, but in May many shoots withered in the trenches planted with healthy seed of the Red Mauritius variety. This variety was taken from a diseased field and was so generally infected that the ratoons nearly all died out. It is probable that many of the apparently healthy canes contained *Colletotrichum*, for, as will be shown below, while reddening of the pith is a sure indication of disease, unless the canes have been mechanically injured, absence of reddening does not always imply freedom from it.

In 1908, the cane selected was again Red Mauritius, which was planted on March 6th. Germination was good in all the trenches. The condition of four rows, Nos. 12 to 15, on May 30th, is graphically shown below, the small circles each representing a sound shoot. Rows 12 and 14 were from diseased seed, rows 13 and 15 from healthy.



Besides these comparative experiments, the main crop of cane grown on the Pusa Farm has been yearly supervised, so that setts showing red marks in the pith are not planted. The result has been that, excepting the season 1907-08, which will be separately con-

sidered as the cane was weakened by an attack of sugarcane-fly, no serious outbreak of red rot has occurred since 1905-06. The disease is always present and was fairly bad in Yerra in 1905-06 and in Red Mauritius in 1906-07, in both cases accumulating in the following 1st ratoons so as to destroy most of the crop. In 1908-09 it was difficult to find enough diseased cane to supply cultures for experimental work. In other years we have had 5 to 10% diseased. These results are probably better than in any other estate in Bihar, though recently several estates have adopted sett selection. In one such case, that referred to on page 198 of the Agricultural Journal of India for 1907, a very severe attack of red rot occurred in 1905. Sett selection has since been carried out as a routine practice and the Manager reported recently that he has now no disease in his crop.

At the Samalkota Sugar Station in Madras, sett selection has been regularly carried out for the past ten years, at the instance of Dr. C. A. Barber, now Government Sugarcane Expert, Madras. Dr. Barber was, we believe, the first to advocate this method of fighting red rot.[1] In the beginning it was combined with pickling the setts in a strong mixture of lime water and carbolic, with a view to checking moth-borer and the Queensland Acarus "rust", but this was subsequently not considered necessary. In 1906, Dr. Barber stated that it was not possible by the mere rejection of red-marked setts to root out the disease[2]. In spite of all care all but two of the local kinds were found gradually to become worse, until they had to be replaced by new seed from outside. Once these had been discarded, however, better results were obtained. Thus the 1907 report states that selection had a satisfactory effect, disease becoming less every year among the best varieties. In 1908, a severe storm at the end of September was followed by withering of a good many canes. Both Dr. Barber and the senior writer saw the crop in the following February and

[1] Sugarcane in the Godavari and Ganjam Districts. Dept. of Land Records and Agriculture, Madras, Bull., Vol. II, No. 43, 1901, p. 188.

[2] Barber, C. A. Scientific Report of the Samalkota Agricultural Station for the year ending 31st March, 1906, p. 25.

agreed in considering it remarkably free from red rot, and in holding the injury to the roots caused by the storm responsible for most of the damage. We also found evidence of the existence of a root disease not previously known, which will be described in a subsequent paper. In 1909-10, red rot was still present on the farm but to a far less extent than heretofore. In 1910-11, very little disease was noted either on the farm or in the nursery, though it was still fairly prevalent outside the farm. In 1911-12, red rot was present only to a small extent, though found in nearly all the varieties. From these records it is clear that red rot has not been stamped out by sett selection. It is equally clear that the disease is much less prevalent than in the early years of the existence of the farm. The farm was started as a result of a disastrous outbreak of red rot in the Godavari Delta, which threatened the extinction of cane cultivation in that area. It is fair to assume that the local varieties, which were at first grown, were very largely from diseased stock. So long as these varieties were retained, sett selection did not give satisfactory results. When they were replaced by other, comparatively healthy varieties, sett selection was effective in keeping the disease under control.

It is now necessary to consider why sett selection has proved ineffective in checking disease when the seed was taken from a severely diseased crop.

In selecting healthy setts for planting under field conditions reliance must be placed on the absence of obvious reddening of the pith, visible at the cut ends. Disease was severe in the Pusa crop of 1907-08 and the opportunity was taken of testing how far this method could be relied on. On November 21st, 1907, 6 canes were selected which, on cutting into lengths, were found to have reddened internodes above and below, but in the middle to be free from obvious reddening. In 3 of these, careful examination with a lens revealed one or two fine reddened points, corresponding with the cut ends of small bundles; the other 3 appeared quite free from discoloration. Slabs were cut out aseptically and incubated, and the presence of *Colletotrichum falcatum* was demonstrated in one of the six. On

March 17th, 1908, the experiment was repeated with 24 canes slightly reddened at the base but apparently clean higher up. Slabs were cut from above the limit of the discoloration. Of these 15 showed no marks even with a lens, while 9 had minute red points. The presence of *Colletotrichum* was demonstrated in 3 of the former and 1 of the latter. Therefore, in an attack of the severity described, nearly 17 per cent. of apparently clean slabs, taken from canes slightly affected with red rot, were shown to contain the fungus within their tissues. Under such circumstances it would have been necessary to discard all canes, any part of which was discoloured: new infections were occurring right up to harvest time and some would probably have escaped even such rigorous selection. It would be cheaper and more satisfactory under ordinary estate conditions to discard the whole crop and import healthy seed. In Pusa, since the amount of seed required was small and questions of cost and trouble did not arise, it was found possible to retain some of the more valuable varieties and the 1908-09 crop had little disease. The amount discarded was, however, very great and would have been ruinous under estate conditions.

All that can safely be stated, so far, is that planting setts from obviously diseased canes leads to a considerable development of disease in the resulting crop and that, provided the variety is fairly free from disease to start with, sett selection keeps red rot within reasonable limits, unless some untoward circumstance, such as the epidemic of cane-fly at Pusa in 1907-08, intervenes.

The infection of sound setts.

If there were no other method of perpetuating red rot than by the use of diseased seed, one could, of course, stamp it out, even in view of the above facts. This brings us to the consideration of the parasitism of *Colletotrichum falcatum* and of the means at its disposal for obtaining an entry into previously healthy cane. We can then more readily discuss the further measures for its control and the influence of external conditions, such as the attack of cane-fly at Pusa in 1907-08 on the prevalence of the disease.

As was pointed out formerly,[1] this fungus is not, in Northern India, provided with as suitable a mechanism for spore distribution as in the case with most parasitic fungi. As long as the cane is growing, there is comparatively little risk of air-borne contamination from the stems of diseased plants in the crop. Dead and rotting canes are, however, frequently well provided with spores. Enormous numbers are often found in the pith cavities of old canes. These may contaminate the soil or get into the irrigation water. They may thus reach the newly planted setts. Several experiments have been carried out to ascertain whether infection of sound setts may take place in this manner.

In 1908, a short trench of Purple Mauritius cane was planted on March 7th, the setts in one-half being previously dipped into a suspension of *Colletotrichum* spores, from a pure culture, in distilled water. On April 30th there were 13 living shoots belonging to 12 setts in the non-inoculated half and 6 belonging to 6 setts in the inoculated.

Similar experiments on a larger scale, in 1909, gave conflicting results, both inoculated and control canes showing a number of withered shoots after two months. On May 14th there were 167 healthy shoots and 27 withered in the control trench and 174 healthy and 40 withered in the inoculated. White ants were bad in both, but there was also evidence that *Colletotrichum* had reached the control trench, probably on the feet of the farm labourers, who walked up and down from trench to trench during the irrigation of the crop.

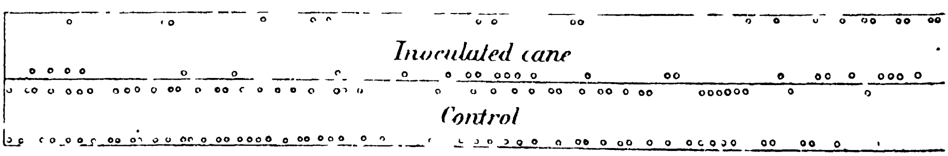
In 1910, the experiment of the previous year was repeated, the cane being sown on March 12th. Germination was slightly better in the control than in the inoculated trench and on May 3rd there were 325 shoots in the former and 304 in the latter. The control trench, which immediately adjoined the inoculated one, developed red rot as in the previous year, probably from infection during irrigation. A similar trench some 30 yards away, but supplied by a separate distributary, was, therefore, also selected for comparison. On June 21st there were only 255 healthy shoots left in the

[1] Butler, E. J., *loc. cit.*, 1906, p. 16.

inoculated trench, while there were 340 in the control trench and 784 in the trench further away.

A form of *Colletotrichum falcatum* which is truly parasitic on the leaves of sugarcane, was described and figured on page 13 and plate III, fig. 9 of the previous Memoir, and has also been found in Louisiana.[1] The ability of this form to cause typical red rot when introduced through setts has been demonstrated, as the following experiments show. As these experiments have a definite bearing on the question of the propagation of the disease through the setts they are included here, though the leaf form of the fungus will be more fully considered below.

On December 5th, 1907, 21 canes of Red Mauritius were inoculated from a pure culture of the leaf parasite shaken up in distilled water. The inoculations were done by removing a cylinder of cane at a lower internode with a small sterile cork borer, inserting some of the culture in the wound and replacing the cylinder after cutting a piece off the end with a flamed knife, so as to leave a cavity. The stem was then bound with fine sterile gutta-percha sheeting. On March 6th, 1908, the inoculated canes were cut and examined. One had been damaged by a jackal and was discarded. The others were outwardly sound. With 18 of these a trench was planted on March 7th, the canes being cut into the usual setts each with three "eyes." In cutting it was observed that obvious reddening of the pith occurred in from 1 to 3 internodes above the seat of inoculation. The remaining two canes were examined microscopically and the presence of *Colletotrichum* demonstrated. A similar trench was planted alongside, with sound setts from the same plot, to serve as a control. The condition on May 30th is shown graphically below. Red rot was severe in the inoculated trench and practically absent in the other.



[1] Edgerton, C. W., *loc. cit.*, p. 4, Pl. I.

On March 7th, 1908, a short trench of Purple Mauritius was planted, half with setts dipped in a pure suspension of the leaf form of *Colletotrichum*, the other half not inoculated. On April 30th, 62 healthy shoots belonging to 50 setts were found in the latter and 30 belonging to 26 setts in the former. Germination had been approximately equal in the two halves.

On March 12th, 1910, half a trench was similarly planted with setts of Ashy Mauritius, dipped in a pure suspension of the leaf form of *Colletotrichum*. Germination was better in the inoculated than in the control half, and on May 3rd there were 182 shoots in the former and 130 in the latter. On June 21st there were 77 healthy and 80 withering shoots in the inoculated half-trench, while the control half-trench had 156 healthy and 55 withering. As already stated the controls this year developed red rot, probably from infection during irrigation. A full trench of the same cane near by but supplied by a separate distributary had, as above mentioned, on this date 784 healthy shoots.

In all these cases the presence of *Colletotrichum* was demonstrated in several of the withering shoots, and they establish fully that true red rot can arise from infection from both the stem and the leaf forms of the fungus through the planted setts. Not only is the disease perpetuated by planting previously diseased setts, but healthy setts can be infected at the time of planting, if reached by the fungus, and, no doubt, subsequent infection from below ground can also occur. It is well known from previous work that the fungus can enter at wounds exposing the pith, such as the cut ends of the setts, and, as will be shown below, infection through the roots also readily occurs. The course of the infection up into the stem can be traced in many cases and direct connection between the mycelium in the sett and that in the new shoot established. Raciborski[1] has very correctly described the passage of the disease from the planted sett up into the young shoot.

[1] Raciborski, M. De Bestrijding van het rood-snot. Archief v.d., Java-Suikerindustrie, V, 1897, p. 1133.

THE INFECTION OF GROWING CANES.

It is generally stated by workers outside India that red rot frequently arises from wound infection of the stem of the cane, after it has developed far enough to be exposed to the attacks of stem borer, that is usually in the second half of its growth period. Some observers even hold that this is the only way in which the disease can arise. The results of numerous inoculations, indeed, fully prove that cane can be artificially infected through wounds similar to those caused by insects. But, as was definitely stated by Prinsen Geerligs[1] in 1898, wound infection will not sufficiently explain every case of attack and we hope to show that in Northern India it is of secondary importance.

Went, who first described the disease, obtained successful inoculations by puncturing the rind with a fine needle and inserting conidia of *Colletotrichum*.[2] The infection was, however, localised and after 20 days was chiefly confined to the inoculated internode, traces only being found in the two higher up. Attempts to inoculate the unwounded rind failed, except when very young internodes were selected. Went concludes that natural infection occurs chiefly through the holes made by boring insects, but that the place of insertion of the leaf sheath at the node is also permeable. Howard, ten years later, described the results of inoculations with the same fungus in the West Indies. When wound inoculations were made on vigorously growing canes about 6 months old, the fungus was found to have infected one or two internodes only, after two months. In fully grown cane, during the ripening period, however, infection was much more complete, up to 18 inches of the pith being invaded in less than a month, in one series. Inoculations at the leaf bases were successful in some cases but failed in others. Lewton-Brain[4] did a limited number of inoculations in Hawaii in

[1] Archief, VI, 1898, p. 160.

[2] Went, F. A. F. C. Het rood snot. Mededeelingen Proefstation West Java. Archief v. d. Java Suikerindustrie, I, 1893, p. 265.

[3] Howard, A. On some diseases of the sugarcane in the West Indies. Ann. of Bot. XVII, 1903, p. 373.

[4] Lewton-Brain, L. Red Rot of the Sugarcane stem. Exper. Sta. of the Hawaiian Sugar Planters' Assoc., Div. of Pathology and Physiology, Bull. 8, 1908.

1906-07. Wound inoculations on the stem of Yellow Caledonia (White Tanna) canes were made. After two months the inoculated internode was found to be infected and there appeared to be indications that the disease was spreading through the nodes to the internodes above and below. Ten months later, no further progress had been made. Presumably the inoculations were made on young plants. Infection through borer holes is considered by this writer to be practically the only way in which fresh attacks arise, but the propagation of the disease by planting diseased setts is accepted. Edgerton[1] reports a very large series of inoculations in Louisiana. He states that the disease spreads from the point of inoculation up and down through the cane for from two to five joints during the season, but is not visible externally. Sometimes, however, if the stalk is inoculated very young, the growth of the fungus is so rapid that the whole stalk is killed, but this is not usually the case. Infection through borer burrows is stated to be by far the commonest cause of the disease. Infection through the leaf bases and the root let buds at the nodes is considered possible but was not proven. Infection through the planted setts is denied. Selection of setts is advocated, not because they can carry red rot but because the resulting crop should be superior if only healthy seed is used.

Quite recently the results of inoculation experiments by South and Dunlop in St. Kitts and Barbados, are described in the "Agricultural News" (Vol. XII, Nos. 286-7-8, 1913). In the St. Kitts experiments wound inoculations at the nodes and internodes caused limited infection, which ceased to develop after about the first month. In the more susceptible canes the fungus spread quickly throughout the entire internode, but did not penetrate the joints. The cane was strongly growing White Transparent, seven months old. Inoculations on the leaf scars and between the leaf sheaths and the stem failed. Attempts to infect cuttings gave more complicated results. All the inoculated cuttings were reddened throughout after 83 days, while only about half the controls showed reddening

[1] Edgerton, C. W., *loc. cit.*, p. 5

in every node and this was less intense as a rule. The latter cuttings had generally a white strand along the side from which the shoots arose. Of 30 inoculated cuttings 8 growing points were found to become diseased; a similar condition was observed in two controls. In one inoculated shoot *Colletotrichum* was identified. The control shoots were more numerous, weighed more and were generally more healthy in appearance than those from inoculated cuttings. In Barbados, 40 setts each of White Transparent, Bourbon, B 147 and B 376 were inoculated before planting, a parallel set being grown as controls. The inoculations took, but growth within the setts was slight, the discoloration being only visible for about 2 by ½ inch round the wound after 6 weeks. There was no definite sign of penetration into the buds at this period. After three months there were 7 withered shoots in the controls and 15 in the inoculated cane. *Colletotrichum* could not be found in the diseased growing tips. The healthy shoots were cut off from the inoculated setts by the formation of a woody partition. The authors conclude that the fungus is a facultative wound parasite, infecting chiefly through wounds such as borer holes, and not carried into the young shoots from infected setts.

Since it is fully established that stem wounds allow of artificial infection, experiments were carried out with a view to ascertain how far this is a common origin of the disease in nature. Practically the only wounds which open a passage direct to the pith are those due to the various stem borers so commonly found in cane. These wounds were tested for *Colletotrichum* on several occasions.

In November, 1907, when red rot was prevalent at Pusa, six canes with borer holes were examined by cutting out aseptically a slab to include the reddened area always found in the immediate vicinity of the hole. On incubation none gave *Colletotrichum*. In the same month the following year the experiment was repeated with 9 bored canes. The result was again negative. In January, 1909, 12 bored canes were similarly examined at Samalkota, with the same result. In addition we have examined by sectioning the neighbourhood of the holes in bored canes on many occasions when the

crop was suffering more or less severely from red rot and have not been able to satisfy ourselves in any case that the disease had originated at the borer hole and not elsewhere. Yet we are satisfied that there are other methods of infection than from below ground and these may now be considered.

Went and Howard both refer to infection through the scar left when the leaf sheaths break away from the stem. In December, 1907, 20 Red Mauritius canes, almost fully grown, were inoculated at the scar left by pulling off a leaf about the centre of the stem. The leaves were old and came away readily. The inoculated portion was kept moist for about 24 hours by covering with moist sterile cotton wool. After three months the canes were examined. One was damaged by a jackal and was discarded. In 3, acervuli with spores of *Colletotrichum falcatum* were found on the surface of the scar. In 11, there was no reddening of the tissues and no sign of penetration. In 5, there was slight reddening at or near the node. No hyphæ, however, could be found and on incubating slabs, cut so as to include the reddened parts, no *Colletotrichum* developed. Even in the 3 cases where the fungus had fructified on the spot, no penetration occurred.

At the cane node there are two other points of discontinuity in the rind, where the shoot bud (the "eye") comes through and where the eyes of the adventitious roots occur. These were found to admit the fungus readily. In April, 1912, 12 buds of Samsara cane were injured by rubbing with the fingers and inoculated with spores and mycelium kept moist by cotton wool as before. One was examined after three days and the hyphæ were found to have penetrated the bud and to be growing vigorously. After eleven days another was examined. The mycelium was still confined to the bud, which was much reddened. A week later the rest were examined. All had taken the infection well and in several the hyphæ had already entered the main stem. Injury to the eye buds, especially as the cane approaches maturity, is unfortunately only too common, and the fungus can readily penetrate if such buds become contaminated. The uninjured

bud is less readily infected. Inoculations made by placing on the bud scales, in a moist atmosphere, fresh acervuli with spores, from a pure culture, showed little progress at the end of a month. There was a slight reddening of the scale, especially along the margin and hyphæ were numerous in the reddened part. The underlying bud layers were only faintly discoloured and very few hyphæ had entered them. The deeper layers of the bud were quite free. The buds were swelling at the time of inoculation and the progress of the infection was so extremely slow that it is doubtful if the young shoot could be reached before the outer layers had withered or lost contact with it. This is in harmony with our general experience that uninjured young shoots are not found attacked by red rot, unless the parent stem is also infected.

The adventitious root eyes are much more easily infected. Twelve Samsara canes were inoculated, in the same manner as in the last experiment, on April 16th, 1912, the root origins being prominent but quite sound and uninjured. On the 24th, 9 were examined and were all found infected, the hyphæ being well established and growing in towards the pith of the main stem. The experiment was repeated on May 22nd, 1913. Four perfectly healthy canes of a thin variety which had a good development of young, clean, adventitious roots, varying from about one-eighth of an inch to one inch in length, were inoculated in the laboratory in the manner described above. The culture used was five days old and 16 roots in all were inoculated. One root was sectioned after a week and found to have taken infection well. The penetration of the hyphæ into the tissues was clearly visible and is shown in fig. 3. Reddening had extended down the root and penetrated about 1½ mm. into the main stem. Characteristic hyphæ of *Colletotrichum* were found in the reddened part of the stem. Two days later 3 more roots were examined, and the same conditions found. On this day the rind at the base of the root was found slightly discoloured and the discoloration extended during the following days, until it was clearly visible externally in all the inoculations. The normal dark green colour of the rind changed to a dirty mottled red, which spread

in vertically elongated streaks and, at the end of the 2nd week, entirely surrounded the node and had extended for an inch or two above and below. After twenty days several inoculated roots were examined at their origin from the stem and large quantities of hyphæ were found passing from the root to the stem, not only along the vascular tissues but also laterally into the stem parenchyma in all directions. Fig. 5 shows the conditions at this stage. The stems were split longitudinally a month after the inoculations and were found entirely infected, the characteristic pith discoloration, with transversely elongated white blotches, being well developed.

Further inoculations were made on June 3rd, 1913, on the feeding roots of well-established cane plants growing in large culture pots in soil. The soil was carefully removed until the roots were exposed and these were inoculated by sprinkling with a suspension of spores from a pure culture, care being taken not to injure the roots. The soil was then replaced. After sixteen days two of the inoculated roots were examined by sectioning. Both showed a small area of reddening 2 or 3 mm. behind the growing point. Penetration was found to have occurred here (Fig. 4) and the hyphæ were extending freely in the tissues of the root.

Out of many hundreds of canes affected with red rot examined during the past ten years, we have met with a limited number of cases where natural infection had occurred through some part of the stem above ground and where the base of the cane was unaffected. In February, 1910, a Khari cane was examined and was found to show definite symptoms of red rot in the 5th and 6th internodes from the base, the lowest internodes being quite free from reddening or hyphæ. At the node between the two infected internodes there was a broken shoot, distinctly reddened in its interior. Characteristic hyphæ of *Colletotrichum* were found in this shoot and could be traced from the broken surface through the bundles into the pith of the stem. There were no other injuries, and infection had doubtless occurred through the broken shoot. A second cane of the same variety showed a similar case of infection through a broken shoot at the 5th node. Higher up several nodes showed slight infection,

which was traced in every case to an infected adventitious rootlet eye. At the 20th node there was another broken shoot, through which infection had occurred. In all these cases, sections taken so as to include the shoot or root and the main stem, enabled the hyphæ to be clearly traced from one to the other. In another case infection occurred through root eyes at the 15th node and also in the 8th internode through a crack in the rind. This is one of the few cases where infection has been found arising from a definite stem wound. The cane was also affected with smut (*Ustilago Sacchari*).

From the above experiments it appears that wounds caused by boring insects, while undoubtedly capable of admitting the parasite should it reach them, are not, in practice, responsible for many cases of red rot in India. Old leaf scars are not readily penetrated, but since infection through the leaf bases has been obtained by Howard, this probably depends on the degree to which abscission has progressed at the time of inoculation. Under normal conditions the leaf scars are not exposed until the leaf has completely withered and, as our inoculations show, such scars are not readily infected. During the process of wrapping, which is common in parts of India, less completely withered leaves are sometimes torn away from the stem, and the scars left in these cases are probably a source of danger. In a few cases the cracks which form in the internodes of some varieties probably admit the fungus. One such case is recorded above. But the commonest points of entry in new infections of the above ground stem, in India, are undoubtedly the shoot and root eyes at the nodes.

THE SOURCE OF INFECTION IN NEW ATTACKS.

We now come to another aspect of the subject and that is the source of infection in those cases in which new attacks occur in the cane stem. Practically all observers are agreed on the comparative rarity of the sporing stage on the surface of diseased cane stems, until these have dried up more or less completely. When we consider the extraordinarily abundant production of spores in most

fungi which depend on the wind for their dissemination and the chances of the individual spore alighting on a susceptible part of the cane stem, this point becomes of significance. But, as was pointed out in 1906, there is another part of the cane on which a fungus agreeing in morphological characters with *Colletotrichum falcatum* is frequently found and produces spores in greater quantity and more exposed to the wind than the stem form. This is the midrib of the leaf. Earlier writers have reported the occurrence of the fungus as a saprophyte on old, withered leaves of sugarcane.[1] That it also occurs not uncommonly as a leaf parasite seems to have escaped the notice of most observers, though Edgerton[2] refers to it. Experiments were carried out at Pusa to determine if the leaf form could infect the stem and conversely.

Three of these experiments have been described above (page 158) where it was shown, firstly that wound inoculation with a pure culture of the midrib form caused visible infection of from one to three internodes after three months and, when the inoculated canes were planted, red rot developed in them with severity, and, secondly, that inoculation of the setts, immediately before planting, causes just as severe disease as when the stem form of the fungus is used. In another case a pure culture of the leaf fungus was used to inoculate Striped Mauritius cane, 11 inoculations being made towards the base and ten towards the apex of the stem. In a little over two months, 7 of the former were examined and showed 7 + 3 + 2 + 1 + 0 + 4 + 4 internodes affected. In 6 of the canes inoculated towards the apex, 3 + 1 + 0 + 1 + 1 + 2 internodes were found diseased after the same period. These experiments show that the leaf fungus can attack the stem and the cut setts, the symptoms produced being those of typical red rot.

The parasitism of the midrib form was next tested on leaves. In the first experiment spores from a pure culture were sown in drops of water on the upper surface of the uninjured midrib of growing canes. Out of 6 inoculations, none succeeded. The ex-

[1] Went, F. A. F. C. Notes on Sugarcane Diseases. Ann. of Bot. X, 1896, p. 588.
[2] Edgerton, *loc. cit.*, p. 4.

periment was repeated on 4 shoots in the laboratory, kept under bell jars to prevent the inoculated spot from drying rapidly. These also failed. In a third series, similar to the last, 6 inoculations were made without result. A month later, however, out of 12 similar inoculations, 5 succeeded. When the midrib was wounded, much better results were obtained. In the first trial 5 leaves were inoculated in plants growing in tubs in the laboratory, the upper epidermis being first removed by scraping with a sterile knife and the spot, after inoculation, being covered with damp sterile cotton wool to keep moist. All succeeded well, the characteristic red discoloration being well developed by the 9th day. In another series, 4 inoculations were made after injuring the epidermis of the midrib by touching it with a hot knife blade for 2 or 3 seconds. All took the infection severely. Four more were inoculated on another occasion, after scraping off the epidermis, and again all took.

Experiments were next made to test the parasitism of the stem form of *Colletotrichum falcatum* on the leaves. In the first experiment, spores from a pure culture were sown in drops of water on the upper surface of the uninjured midrib of canes growing in a tub in the laboratory. Of 15 inoculations, none succeeded. The experiment was again tried and of 7 inoculations, all succeeded. In a third series, out of 13 inoculations, 5 succeeded. When the midrib was wounded before inoculation the results were as follows. In the first trial 5 inoculations were made after scraping off the epidermis. The inoculated spot was covered with a pad of damp sterile cotton wool. None succeeded, the fungus growing by choice into the cotton wool. A similar experiment at a later date was made on 3 shoots standing in water, no cotton wool being used but the shoots being covered by bell jars. All succeeded. In a third experiment, the epidermis was injured by touching with a hot knife blade and all of 4 inoculations succeeded.

Though both leaf and stem forms, are capable of penetrating uninjured leaves, infection occurs much more readily when the leaf is wounded. The microscopic details of penetration will be described below. In nature, it has been observed that *Colletotri-*

chum is common around the hole which a minute boring insect frequently makes in the midrib. Salmon[1] has found in similar experiments with the mildews (*Erysiphaceæ*) that "green fly" (*Aphis*) has the same effect as a wound, in weakening the resistance of the plant cells to infection.

From these experiments it is apparent that there is no essential difference in the ability of the forms of *Colletotrichum*, found on the living midrib of the leaf and on the stem, to attack stems and leaves of sugarcane. Taken in conjunction with their morphological similarity, they must be held to be the same fungus. The species appears to be confined to sugarcane. The only other *Colletotrichum* resembling *C. falcatum* found widely distributed in India, is *C. Lineola* Corda, which attacks the leaves of jowar (*Andropogon Sorghum*) frequently. Morphologically the two species are closely allied, but the jowar fungus does not attack cane leaves. Out of 16 inoculations, half on unwounded spots on the midrib, half after scraping off the epidermis, none succeeded. Edgerton[2] failed to get symptoms of red rot by inoculating sugarcane stems with this species and also with the allied *C. cereale*. It is probable that many of the new attacks of red rot on the above-ground part of the cane stem, arise as a result of infection by spores blown from the diseased midribs of cane leaves. We do not see how it will ever be possible to avoid this, but it only gives greater force to the arguments in favour of concentrating attention on the elimination of diseased setts at the time of planting.

The actual penetration of the fungus into the tissues was studied in the leaf inoculations. Including both leaf and stem forms, altogether 63 inoculations were made on the uninjured midrib, of which 17 succeeded and 46 failed; while when the epidermis was wounded 20 out of 25 inoculations succeeded. In the successful cases where the epidermis was uninjured, penetration usually occurred not directly into the midrib but by superficial growth of the fungus until the large motor cells lying in groups on either side

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[1] Salmon, E. S. Cultural experiments with "Biologic forms" of the *Erysiphaceæ*. Phil. Trans. Royal Society, Ser. B, Vol. 197, 1904, p. 112.

[2] Edgerton, C. W., *loc. cit.* p. 7.

of the midrib were reached; these were then penetrated (Fig. 1). As is already known, the germ-tubes of the spores readily form appressoria (described under the name of "gemmæ" by Went and of chlamydospores by most other writers). These are thick-walled, durable cells, capable of surviving detachment from the mycelium. It is probable that they serve a double purpose of close adhesion to the surface of the host plant and of accumulation of enzymic energy to secure penetration of its walls. In *Colletotrichum falcatum* the infection hypha seems to arise as a rule from an appressorium (Figs. 1 and 2). Entry through stomata was not observed, the infection hypha passing directly across the outer wall of an epidermal cell, or, in some cases, down between the side walls of two cells. After entry, the hyphæ may at once branch freely and fill the large motor cells with a mass of mycelium, or may penetrate deeply into the leaf, passing from cell to cell with ease in the large-celled parenchyma between the bundles, but not readily entering the latter. In some cases the sclerenchyma was penetrated, but usually, when the leaf had not been injured before inoculation, the hyphæ remained, for the first week at least, confined to the thin-walled cells. In the cases where the leaf was first wounded, conditions were somewhat different. There was a superficial growth as before, extending beyond the limits of the wound. But penetration was not now confined to the thin-walled motor cells but occurred freely into the epidermis of the midrib just beyond the wounded part (Fig. 2), and the mycelium ramified through the sclerenchyma as readily as through the parenchyma. In some cases, the layers of underlying sclerenchyma left after removing the epidermis, were an effective barrier and penetration only occurred beyond the midrib into the thinner tissues between the bundles, but in others, presumably when the injury was more severe, the thick-walled tissues showed much mycelium. All the invaded tissues developed a bright red colour.

In less than a week fructification may occur on the infected spot. The hyphæ first collect in masses in the epidermis, through

which they then break as stromatic bodies, on which the characteristic spores and sterile hairs are formed.

Relative susceptibility of the top and bottom of the cane.

Experiments were recorded in the previous Memoir[1] to show that much of the damage caused by red rot is due to inversion of the cane sugar. This appears to be because glucose is more readily assimilated by the fungus, growth in solutions in which the sugar was provided as glucose, being invariably better, at least at first, than when cane sugar was supplied. Flasks were prepared with solutions containing 10 per cent. cane sugar and glucose respectively together with peptone and sodium chloride, and inoculated with a loop of a suspension of spores, from a pure culture, in distilled water. The growth in the glucose flasks early took the lead and maintained its superiority for some weeks. More recently, Lewton-Brain[2] has dealt with the same question in considerable detail. He found that the inverting action of the fungus was considerable, but that, as stated in the previous Memoir, the actual consumption of sugar was small. This consumption, he found, fell entirely on the levulose. Thus in one experiment, though 75 per cent. of the sucrose was inverted, not one-twentieth part of this was actually consumed by the fungus and this appeared to be all levulose. The inversion was proved to be due to the presence of invertase, which was found both in the mycelium and also in the solution in which the fungus was grown.

Since it is known that the upper portion of the cane is richer in glucose, though poorer in total sugars, than the lower[3], experiments were made to compare the growth of the fungus in the top and bottom portions. In the first experiment, 3 sound Striped Mauritius canes were cut and brought to the laboratory. They were each inoculated at a lower and an upper internode by removing

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[1] Butler, E. J., *loc. cit.*, 1906, p. 7.

[2] Lewton-Brain, L., *loc. cit.*, 1908, p. 32.

[3] Leather, J. W. Chemical composition of sugarcane and raw sugars. Agric. Ledger, No. 3 of 1897, p. 13.

a cylinder aseptically with a small cork borer and inserting a small quantity of a pure culture of *Colletotrichum.* After eight days they were examined. The lower inoculations were found to have infected 2 + 2 + 1 internodes respectively, the upper 1 + 2 + 4. The experiment was repeated with Samsara canes, 6 being inoculated in the same way. After seven days one was examined and was found to have 2 internodes infected at the base and 1 at the top. Two days later another was examined, 5 and 2 internodes respectively being found infected. Two days later the rest were examined. In one the infected portions had united in the middle. In the other three, 11 + 10 + 7 internodes were found infected at the base and 3 + 5 + 2 at the top. The experiment on page 167, where inoculations with the leaf form of the fungus were made at the top and bottom of growing canes, should also be compared. As the practical point at issue was to determine if any recommendations could be made for planting one part of the cane rather than another, where red rot is prevalent, the natural inversion that goes on after cutting was not taken into account, since it must equally go on in planted setts before germination. The experiments do not suggest that tops, though richer in glucose, can be more rapidly invaded by *Colletotrichum* than the rest of the cane and there appears to be no objection to their use from this point of view. The second experiment and that given on page 167, indeed suggest that the contrary is the case. Tops are also less likely to contain the fungus, when it has originated from below at a late stage in the growth of the cane.

CONTROL OF THE DISEASE.

The control of red rot was stated by the earlier investigators to be likely to be very difficult, owing to its position in the interior of the cane, the frequent absence of definite symptoms by which it might be detected in the growing crop and the practical impossibility of preventing wounds which would give an entry to the fungus. But of recent years little has been heard of the disease in Java, where it was first described, and it may be concluded that it has not proved so serious an enemy as was once feared.

In India it is in many places the greatest obstacle to successful cane cultivation. In Madras, Bombay and Bengal the area under thick cane has in certain districts periodically shrunk as a result of an accumulation of red rot in the crop, to expand again only when the diseased cane has been replaced from outside. Red rot has often been the limiting factor to the successful cultivation of heavy yielding canes.

The experiments given above are, we think, sufficient grounds for holding that this should not be the case; that, granted that a start is made with a healthy stock, it should be possible to keep the disease under control with no more than an occasional severe outbreak due to a specially unfavourable season.

The first requirement is to start with a healthy stock. In those districts, such as the Godavari Delta and some parts of Bombay Presidency,[1] where the local canes have become widely infected, new healthy seed must be brought in from outside. The very successful history of the Samalkota Sugar Station in the Godavari Delta, shows what excellent results may be obtained by this measure under efficient supervision. It is highly probable that the little that has been heard of red rot in Java, in recent years, has been due to the efforts made to obtain good cane for planting, from special seed nurseries, combined with the growth of seedling canes which will be referred to below. As the Samalkota results are available in the Annual Reports of the Station, the methods adopted need not be more fully detailed. The past history of the cane must be taken into consideration. There is good evidence to show how dangerous it is to grow a variety from stock known to have been seriously infected, even though the crop may do well for the first few years. Large estates or groups of estates should be self-contained in the matter of seed supply and should possess a nursery or testing garden for the trial of new varieties under the best conditions. For the ordinary native cultivation, Government Farms should be utilized for the same purpose. In this way a supply of

[1] Kulkarni, G. S. Preliminary study of the red rot of sugarcane in the Bombay Presidency. Dept. of Agric., Bombay, Bull. No. 44, 1911, pp. 5-6.

healthy seed can be assured and new varieties can be introduced into cultivation as required.

Systematic and thorough selection of the setts used for planting must then be done each year or the new varieties will not maintain their freedom from disease for long. The methods to adopt are described in a previous paper[1] which should be referred to, and present no difficulties in practice. We consider that there is no single operation in the cultivation of thick canes in most parts of India of greater importance than this. It is not to be anticipated that the disease can be got rid of by a single selection nor, indeed, usually got rid of in its entirety by annual selection ; the most that is claimed is that it can be kept within reasonable limits in normal years and with good cultivation. The object of the selection is to prevent an accumulation of red rot to such an extent as materially to reduce profits and render it difficult to obtain a sufficient supply of sound seed for the coming season.

Of lesser importance but still worth doing in most cases, is the regular removal of all withering clumps during the growing and ripening season. Such clumps, if left, dry up and produce spores, sometimes in considerable quantity. Infection of even perfectly sound cane through the aerial root eyes and through injured buds has been shown to occur and though our experience in Northern India has been that such infection is not common, it is perhaps more frequent in Madras, where the disease appears to be more virulent and rapid in its onset than with us. There is, also, the danger of infection through the soil, especially in irrigated cane, by means of the shed spores.

Judging from Godavari experience it is important to give cane a long rotation. How far this results from the peculiar circumstances of cane cultivation in heavy paddy soils. with very frequent irrigation, is not clear. In the Godavari Delta, the old practice was eight or nine years' rest from cane after a two years' cane crop (one year plant cane and one year ratoon). More recently, it has been reduced

[1] Butler, E. J., *loc. cit.*, 1907.

to six years, probably with bad results.[1] At Samalkota a two years' "dry" rotation (not followed by paddy) and a three years' "wet" rotation (followed by paddy) were tried, but found unsatisfactory. On the other hand, at Pusa, cane one year in five has been satisfactory and the non-irrigated cane in Bihar usually gets a much shorter rotation. The fungus appears to die out rapidly in moist soil, but cultures exposed to the air and kept moderately dry retain their vitality for at least five months. In Hawaii, Lewton-Brain found that plate cultures allowed to dry out invariably gave no sign of vitality after three months. But if cane is present, there seems to be little doubt that *Colletotrichum* lives and spreads through the soil and, in the young irrigated crop, passes from trench to trench, either with the seepage of irrigation water, on the feet and implements of coolies or (though less certainly) by direct growth through the soil. It has been shown that the roots are readily infected and we have lost several series of comparative experiments at Pusa through ground infection of control trenches. Fortunately the radius of spread does not appear to be large and if the measures detailed above are carried out, little injury should be caused in this manner.

In spite of all these precautions, serious attacks of red rot, from circumstances not ordinarily under control, may occur from time to time. We have met with two such cases. One was the outbreak at Pusa in 1907-08, which was, without doubt, the result of an epidemic of cane-fly (*Pyrilla aberrans*) on the cane that year. Leaf-hoppers are well known in other countries to be associated with bad attacks of fungus diseases as, for instance, in Hawaii, where "rind disease"[2] follows with great intensity the epidemics of leaf-hoppers. It is probable that the action of these insects is chiefly to reduce the vitality of the cane and render it increasingly sus-

[1] Wood, R. C. Scientific Report for the Samalkota Agricultural Station for 1908-09. Government Press, Madras, 1909.

[2] The cause of this disease is not yet quite clear. Howard in the West Indies and Went in Java held that it was identical with red rot, the fungus, *Melanconium Sacchari*, previously believed to be its cause, being merely a follower of *Colletotrichum falcatum*. Subsequent workers, such as Lewton Brain, Cobb and Edgerton in the West Indies, Hawaii and Louisiana, have reverted to the previous view, though quite recently South and Dunlop have failed to establish the parasitism of *Melanconium Sacchari*. In the East, this fungus has not been recorded as a parasite.

ceptible to infection from aerial spores, which were formed in considerable quantity on the leaves during the outbreak at Pusa. The other case was a severe attack of red rot following extensive flooding of the cane fields, in some estates in Bihar several years ago. The effect of unfavourable external conditions such as this on the onset of the disease is discussed more fully below.

SUSCEPTIBILITY OF VARIETIES OF CANE.

Little light has been thrown by these investigations on the question of the relative susceptibility of different varieties of cane to red rot. One fact that is obvious to any observer of the disease in India is that the thin varieties of cane are, on the whole, less susceptible than the thick. Some of the Indian thin canes are so widely divergent from the thick races, that writers in Java have suggested that they may have originated from different species of *Saccharum*.[1] If so, one may perhaps anticipate that the relative immunity of the thin kinds will prove to be a deep seated "germ" character. With regard to the thick canes, certain observers, and in particular Dr. C. A. Barber, hold that the temporary or apparent immunity of certain thick varieties can be broken down by bad cultivation. He describes[2] how, in the Godavari Delta, successive canes have held favour during the past forty years, each in turn growing luxuriantly and bringing wealth, but after a few years becoming diseased. The constitution of each cane had been broken in turn by the ever present fungus, until all the plants of that kind in the district were infected. Again he states[3] that of the varieties of cane brought from other countries for trial at Samalkota, none were really immune and it is probable that ultimately all will succumb in turn when placed under the adverse conditions of the local agriculture. In the same paper[4] he mentions as a curious fact that the Hospet cane varies greatly in its liability to disease in the different regions where it is found. A similar case occurred with the

[1] Kobus, J. D. Overzicht van het verloop der importatieplannen van vreemde rietsoorten op een eiland buiten Java. Archief v. d. Java Suikerindustrie, II, 1894, p. 662.

[2] Barber, C. A. The Samalkota Sugarcane Farm. Agric. Journ. of India I, 1906, p. 45.

[3] *Ib.* Seedling canes in India. Agric. Journ. of India, VII, 1912, p. 324.

[4] *Ib.* *loc. cit.* p. 329.

Bombay Pundia cane which, when introduced at Samalkota, went out from disease in the first season, though the parent stock is little subject to red rot. Kulkarni[1] also notes the gradual deterioration of thick canes in parts of Bombay, and West Indian literature is full of references to the breaking down in health of the Bourbon cane, once widely grown, and this breaking down seems to have gone on more rapidly in some localities than in others.

These experiences with sugarcane are by no means unique amongst plants ordinarily propagated in a vegetative manner, that is by tubers, cuttings and the like. In Ireland the "Champion" potato was largely cultivated for many years, on account of its resistance to potato blight, but it has lost its resisting powers and been replaced by newer "seedling" varieties. Several similar cases are known, and the phenomenon is of considerable scientific interest.[2] Such progressive deterioration is in many cases apparently innate and has been likened to senescence, being capable of being checked when a new generation is started by sexual reproduction (*e.g.*, by raising from seed). But it can be hastened by exposure to unfavourable conditions or, on the other hand, be postponed by profound change in the environment. Barber states that the surest way to induce red rot in cane to make its appearance is to plant the canes in a water-logged site. Harrison, in British Guiana, considers that the susceptibility of certain kinds of plants for instance, the Bourbon cane, to fungus attacks is due in part at least to defective soil conditions.[4] Such statements can be multiplied and must, we think, indicate a real phenomenon. In the opposite direction are such cases as that recorded by Calkins,[5] where a constantly changing culture medium was found to have the effect

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[1] Kulkarni, G. S. Preliminary study of the red rot of sugarcane in the Bombay Presidency Department of Agriculture, Bombay, Bull. No. 44, 1911.

[2] c. f. Hartog, M. Problems of Life and Reproduction. Progressive Science Series, 1913, p. 19.

[3] Barber, C. A. The Samalkota Sugarcane Farm Agric. Journ. of India, I, 1906, p. 45.

[4] Harrison, J. B. Varieties of Sugarcane and Manurial experiments in British Guiana. West Indian Bulletin, IX, 1909, p. 36.

[5] Calkins, Gary N. Protozoology, 1910, p. 109.

of prolonging the life of the race in Protozoa, bred from a single individual and not permitted to conjugate; when asexual propagation only is allowed and the environment kept constant, the race soon degenerates and dies out.[1]

It is not unlikely, therefore that, there are two types of relative immunity, a genetic, such as is shown by the thin canes so widely cultivated in India, and a fluctuating, and that the latter is much more exposed to the influence of external conditions than the former. Indian thick canes, which have been subjected to vegetative propagation without a break for many generations, seem to show no evidence of genetic immunity. Hence frequent change of climate, good cultivation and good hygienic conditions generally, seem to be of great importance in preserving them from epidemics of disease.

The possession, by India, of a large range of relatively immune (to red rot) thin canes, of hardy habit and great tillering powers. though less productive than the thick canes of other countries, may prove an asset of the greatest value. The growth of seedling canes has been recently undertaken at the Coimbatore cane-breeding station under the control of Dr. Barber. If it is found possible by hybridization to combine the resistance of some of the thin canes to red rot, with the yielding qualities of a thick cane, a great step forward in enabling India to grow enough sugar for her own consumption and perhaps even to compete successfully with the sugar exporting countries, will have been taken. It is a happy augury that amongst the best of the canes now grown in Java (the most formidable competitor in sugar production that India has to meet) are the progeny of crosses between an Indian thin cane, the "Chunnee" obtained from Shahjahanpur (where, Dr. Barber informs us, it is locally called Chin), and the Cheribon thick cane grown in Java.

PUSA,
June 30th, 1913.

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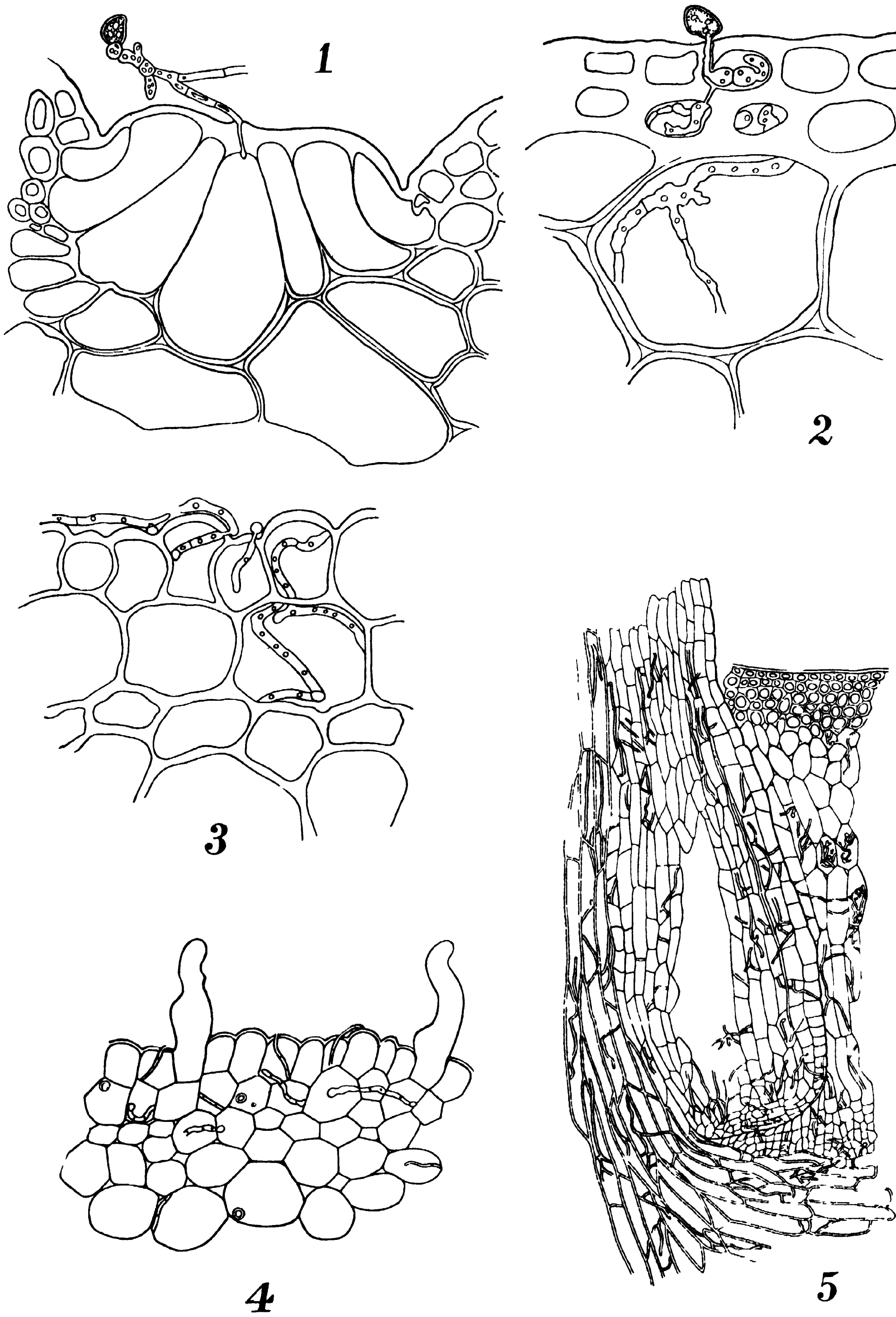
[1] Since this was written a very illuminating discussion of the deterioration of sugarcane varieties after long-continued vegetative propagation, written by Harrison, Stockdale and Ward (West Indian Bulletin, XIII, 1913, p. 177), has been received.

PLATE



Infection of sugar cane leaves and roots by the red rot fungus,
Colletotrichum falcatum.

DESCRIPTION OF THE PLATE.

Fig. 1. Penetration of a hypha, arising from an appressorium of the stem form of *Colletotrichum falcatum*, into a motor cell of the unwounded leaf of sugarcane. The midrib commences immediately on the right of the figure. X 350.

Fig. 2. Penetration of a hypha, arising from an appressorium of the stem form of *Colletotrichum falcatum*, into a cell of the thick-walled part of the epidermis at the edge of the midrib of the sugarcane leaf. The neighbouring central part of the midrib had been wounded by scraping off the outer layers with a sterile knife. X 500.

Fig. 3. Penetration of an adventitious root on the stem of sugarcane by hyphæ of *Colletotrichum falcatum*, through the uninjured epidermis. X 500.

Fig. 4. Penetration of an underground root of sugarcane by hyphæ of *Colletotrichum falcatum*, through the uninjured epidermis. X 300.

Fig. 5. Passage of the mycelium of *Colletotrichum falcatum* from a young inoculated adventitious root, of the same series from which fig. 3 was drawn, back to the main stem of the sugarcane. The hyphæ enter the vascular tissue and the parenchyma of the stem and spread in all directions. X about 50.

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December, 1913 BOTANICAL SERIES VOL. VI, No. 6

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

SOME NEW SUGARCANE DISEASES

BY

E. J. BUTLER, M.B., F.L.S.

Imperial Mycologist

AND

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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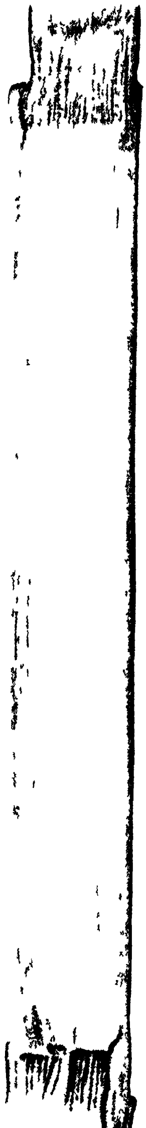

Fig. 1.

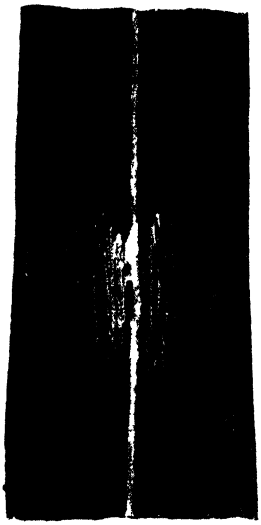

Fig. 3.

DESCRIPTION OF PLATE I.

Fig. 1. Appearance of split cane infected with *Cephalosporium Sacchari*. Natural size.

2. Appearance of split cane infected with *Hendersonina Sacchari*. × 1½.

3. Leaf spot caused by *Helminthosporium Sacchari*. Natural size.

SOME NEW SUGARCANE DISEASES

BY

E. J. BUTLER, M.B., F.L.S.

Imperial Mycologist,

AND

ABDUL HAFIZ KHAN

Assistant to the Imperial Mycologist

I.—Wilt

(*Cephalosporium Sacchari* Butl. n. sp.)

In the course of investigations of the red rot of sugarcane, caused by *Colletotrichum falcatum* Went, a second disease, to which the name red rot might equally well be applied, since it produces distinct reddening of the cane pith, has frequently been encountered. With a little practice the two diseases can be distinguished and they are caused by entirely distinct organisms.

As in red rot, the earlier symptoms are elusive. Except in such cases of severe infection of the cuttings selected for planting as cause the death of the young shoots, in the manner more fully referred to below, little is noticed until the cane is about half grown. At this period affected canes lag in growth and stunted, single stools, or patches of varying size, may soon be observed scattered through the fields in which the disease is prevalent. From this on until the time of harvest, withering of individual canes, or even of whole stools, occurs. The leaves dry up, as if insufficiently supplied with water, followed by the stems, which become light and hollow. If the cane be split longitudinally when the leaves are first observed to wither, a charac-

teristic discoloration of the pith, as shown in Pl. I, Fig. 1, may be observed. A comparison of this figure with a coloured drawing of true red rot* will show the difference in appearance of the two diseases. Instead of bright red patches and streaks, broken by transversely expanded white areas, there is a diffuse purple or dirty-red colouration, in which brighter red, vertical lines mark the position of the bundles. The tendency of the colour to become muddy at an early period is its most strongly marked character and serves to distinguish the disease from any other known to us. In old cases the red almost disappears, being replaced by an earthy brown. The pith dries up more rapidly than when attacked by *Colletotrichum* and becomes hollow. Within the hollow portion, a fluffy grey growth of mould is often found.

Microscopic examination shows that the stem is infested throughout the reddened portion, which may be confined to a few joints or extend to the whole length of the cane, by a fungus, whose hyphæ ramify through the cells in all directions, penetrating the fibro-vascular bundles as freely as the large-celled parenchyma of the pith (Pl. II, Figs. 2 and 3). Most of the hyphæ are fine, not exceeding 3 μ in diameter in recently infected parts, and either uniform or tapering gradually. They pass from cell to cell through the pits in the walls, when pits are present (Fig. 2), but can also penetrate unbroken walls and seem to have no preference for one tissue more than another. Even when old, they remain hyaline. Occasionally they have been found bearing conidia in the vessels (Fig. 5) and possibly do so also in the parenchyma of the pith, as the condition shown in Fig. 4 appears to represent an early stage of spore-formation. The conidia are small, hyaline, unseptate, oval, and usually appear to be borne singly on short lateral branches of the mycelium. They resemble closely the microconidia frequently found in the vessels of plants affected with the *Fusarium* wilts.

* See Memoirs, Dept. of Agric. in India, I, No. 3, 1906, Pl. I, or Agric Journ. of India, II, 1907, Pl XI.

In the hollow which invariably forms in the pith of affected internodes at a late stage in the disease, there is usually a copious greyish-white, fluffy growth of hyphæ, similar to those found in the tissues, and bearing great numbers of conidia, resembling those observed in the vessels, though often of somewhat larger size. The characters of the fungus can be studied from this growth or, more satisfactorily, from pure cultures, and they show it to be a member of the form-genus *Cephalosporium*, several species of which are known to be lower stages in the development of *Hypocreaceæ*.

The hyphæ are hyaline, slender (about 3 to 5 μ in diameter), richly branched, sparingly septate when young, not varying abruptly in diameter, though swollen segments are found in old cultures. Sometimes the individual filaments unite together to form coremial strands, usually only two or three hyphæ taking part in the formation. An early stage of such a strand is shown in Fig. 6*a*. Chlamydospores have not been observed either in culture or in diseased canes.

The conidia are borne on short, simple or branched, lateral hyphæ and also terminally on the ultimate branches of the mycelium. They measure 4 to 12 μ (usually 5 to 8 μ) by 2 to 3 μ, when formed, but increase in size prior to germination. Their shape varies from shortly oval to ovoid or long elliptical. Occasionally they are curved or with one side flattened. They are almost invariably unicellular when formed, but some become septate prior to germination, the septa being 1 to 3 in number (Fig. 11). Spores and mycelium are hyaline.

The conidiophores are usually of definite shape, measuring from 6 to 30 μ by 3 to 4 μ at the thickest part, swollen slightly in the middle or lower third, narrowing below where they arise from the mycelium and tapering above, but with an obtuse apex on which the spores are borne (Fig. 7). They may be scattered along the hypha or arise in bunches near together (Fig. 6). Branching is not uncommon, being irregular or once whorled or forked. Each branch usually bears conidia at the apex, but if kept very moist the branches may grow out into long hyphæ.

The first conidium is borne at the tip of the conidiophore and, when full grown, is pushed to one side by the formation of a second spore at the same point, and so on until a number have been produced. Sometimes, instead of forming a second spore, the apex continues growth as a hypha, which may again bear conidiophores (Fig. 13*a*). Unlike most members of the genus, the successively formed conidia are not held together in a mucilaginous drop, but adhere merely by surface attraction and are very easily dislodged. If kept free from currents of air in a moist chamber, heads of 5 or more can readily be found. They adhere more firmly at the base than elsewhere and if carefully mounted, after treatment with acetic acid, such appearances as those figured in Fig. 7*a* can be observed. At first sight this suggests that the spores arise near together and at the same time, as in the genus *Haplotrichum*, but more careful examination shows that this is not the case, only one spore being formed at a time and the whole apex of the conidiophore taking part in its formation. The apex is pushed out by growth from within the hypha to form the spore, and if examined just after the latter has fallen and before a second appears, the condition shown in Fig. 9 is found. In moist chamber cultures spores formed on the aerial mycelium appear as shown in Fig. 8, lying in a single layer with their long axes parallel. Spore-production is extraordinarily copious, almost every hypha being abundantly provided with conidiophores throughout the greater part of its length.

Germination occurs within 24 hours in many cases, the large septate and small unseptate conidia behaving in much the same manner (Fig. 11). The germ-tube is usually single and terminal, but the septate spores may give out a tube from each end. Union of two or more germ-tubes, belonging to different spores, is common (Fig. 12), up to five spores having been found united in this manner. One or two of the germ-tubes grow out into strong hyphæ from the united mass, the arrangement being probably merely a nutritional adaptation.

In culture on nutrient agar the mycelium remains white and filamentous and no formation of stromata or of other types of

spores has been observed. The species does not agree with any previously described and has been named *Cephalosporium Sacchari*, the diagnosis being as follows :—

Cephalosporium Sacchari Butl. n. sp. Effusum, candidum : hyphis repentibus, parce septatis, 3-5 μ diam. ; conidiophoris continuis, simplicibus furcatis vel subverticillato ramosis, sursum obtusis, medio vel versus basim incrassatis, 6-30 μ long. 3-4 μ crass.; conidiis ex apice ramulorum pluribus continuis exsilientibus et in capitula collectis sed facillime secedentibus, hyalinis, ovoideis vel oblongo-ellipsoideis, continuis, 4-12 ⩔ 2-3 μ.

In culmis *Sacchari officinarum* in India or

Cultures of the fungus can be readily obtained in the same way as with *Colletotrichum falcatum*, by cutting out aseptically a portion of the pith, in the early stage of the disease, and incubating in a sterile Petri dish or potato tube. The growth is frequently pure from the commencement, but if not, can be readily purified by sub-culturing from the aerial mycelium. The following inoculations were carried out with pure cultures from nutrient agar, in which spore-production was copious.

On December 13th, 1908, 20 strong sound Red Mauritius canes were inoculated in a stem wound with a suspension of spores and mycelium in distilled water, from a culture two weeks old. The inoculations were made in the lower half of the cane by removing a cylinder of pith with a small sterile cork borer, inserting a drop of the suspension, and replacing the cylinder after cutting off a little of the end, so as to leave a small cavity. The wound was then bound with sterile gutta-percha sheeting.

The canes were examined after 3 months. In one case only had the whole cane dried up, the infection extending above the wound to the top of the cane, and below for 3 internodes. In the others infection had progressed through from 4 to 6 internodes The inoculated internode had become hollow in every case, those above and below being also hollow in some cases. The symptoms were typical and the fungus was found throughout the discoloured parts.

On the same day 15 canes were inoculated at leaf scars, the scar being covered after inoculation with a wad of damp sterile cotton-wool, bound with gutta-percha sheeting. The same material was used as in the last experiment.

These inoculations also succeeded, distinct reddened bundles being found after 3 months, extending downward from the scar through the next internode. The progress of the infection was less than in the last case and could not be traced beyond the one internode. The hyphæ were found chiefly in the reddened bundles and there was not much lateral spread. It was noticed that shoots arising from the inoculated nodes were not infected.

The fungus cannot penetrate the unbroken rind of the internodes. Sixteen inoculations were made to test this, a drop of the suspension being placed on the rind, and covered with damp sterile cotton-wool for 48 hours. In no case was there the slightest sign of infection.

As in *Colletotrichum falcatum*, however, the adventitious root eyes at the nodes can be inoculated successfully. Ten inoculations were made on the uninjured eyes, in exactly the same way as in the last experiment, except that the cotton-wool was removed after 36 hours. The first sign of success was noticed after 4 days ; one of the eyes being slightly discoloured On sectioning, the hyphæ were found to have penetrated through the epidermis and to have reached almost to the centre of the bud. Three days later all the inoculations had clearly succeeded, the eyes being reddened and full of hyphæ. After 10 or 11 days the eyes were quite killed and the hyphæ were passing into the main stem.

To see if the cane can be infected through the setts at the time of planting, half a trench of Striped Mauritius was planted on March 7th, 1907, after dipping the cut setts in a suspension of spores and mycelium in distilled water. The remaining half trench served as control. Germination was approximately equal in the two halves, but 22 shoots withered in the inoculated half up to June 17th, whereas there were only a few deaths in the other

half, apparently due to white-ants. The *Cephalosporium* was recovered from 3 of the withered shoots examined.

As this fungus has been several times found associated with *Colletotrichum falcatum*, experiments were made similar to the last, but with mixed suspensions of the two fungi, in 1907. The results were striking. Germination was good in both halves of the trench, but 45 shoots withered in the inoculated half in the first three months, while there were very few failures in the rest of the trench. *Colletotrichum* was recovered from 2 of the withered shoots and *Cephalosporium* from 8, out of 14 examined. The experiment was repeated in 1908 with much the same result.

These experiments show that the fungus can enter the cane through wounds, through the uninjured root eyes at the nodes, and through the planted setts. In true red rot the writers have shown* that the latter is the most frequent method of infection in Northern India. In the present case the evidence is not so complete, but it has been found that wound infection is far more common than with *Colletotrichum*. The wounds examined have been all borer holes, which are much the most frequent wounds in standing cane. Altogether 27 have been examined by incubating an aseptically removed slab from just beyond the margin of the hole and, of these, 15 have given the fungus. Out of 9 examined in the 1908 crop when nearly fully grown, 8 were infected. This was the year when the most widespread attack of *Cephalosporium Sacchari* was observed at Pusa.

The disease is found over a large part of India. It has been observed at Surat, Poona, Samalkota and throughout North Eastern India. As a rule it seems to accompany red rot, quite a considerable percentage of the cases examined being due to mixed infection. In the 1908 attack at Pusa, however, there was practically no true red rot and a good deal of damage was done by an unmixed attack of *Cephalosporium*. Similarly, in 1912, several cases of pure infection were encountered, and pure cultures were obtained direct from the mycelial growth in the

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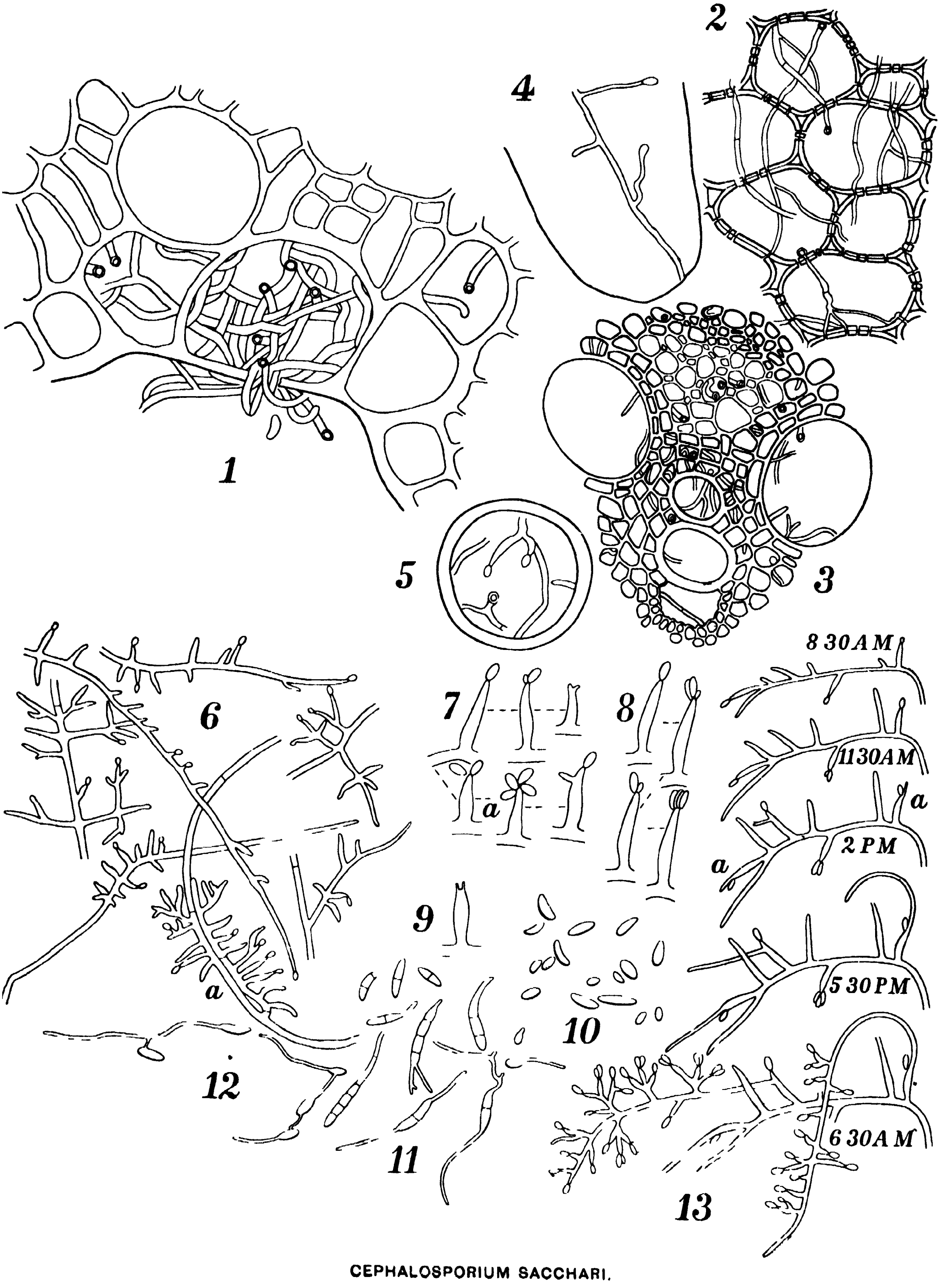
* Butler, E. J., & A. Hafiz Khan, Red Rot of Sugarcane. Mem. Dept. of Agric. in India, Bot. Ser., VI, No. 5, 1913.

hollows of the pith. As a rule, so far as has been observed, the infection is not virulent; spread within the cane is gradual and communication from one plant to another slow. A large number of borer holes become infected late in the season, but the parasite usually seems to remain confined to a few internodes. As bored setts are usually discarded at planting time, infection by this channel is not often transmitted to the following crop. The fungus has not been found on the leaves or on the surface of the stem, in the field. In the laboratory, however, a case of spontaneous infection of the leaf with a fungus exactly resembling that under consideration occurred, and this led to further examination. Inoculations were made with cultures obtained from the growth on the leaf and also with cultures from diseased cane stems Both gave similar results. Six inoculations were made with each of the two cultures. In two cases the inoculated leaf withered too rapidly to allow of definite observations. The remaining ten were quite successful, Pl. II, Fig. 1, showing the condition after three days. Penetration had occurred chiefly through the large thin-walled motor cells. We have not been successful in finding cases of leaf infection in the field, but as leaf spots are extremely common on sugarcane such a search is not easy. The spot caused by *Cephalosporium Sacchari* in artificial inoculations resembles that caused by *Helminthosporium Sacchari*, described in a later section of this paper, and all the field cases examined belonged to this latter fungus.

Rotten canes must set free large quantities of spores and the source of the infection of cane wounds may come from these, from the leaves and, if the species passes part of its life as a soil saprophyte, as is not improbable, possibly also from the soil. The genus is so common in cultivated soils, and this species has so little to distinguish it from some of the habitual soil dwellers, that its recognition would be difficult. It lives very readily as a saprophyte, however, growing luxuriantly on most of the common culture media and remaining alive in culture for about 3 months, so that it is probably present in the soil of cane fields. The inoculation experiments indicate that infection of the setts at the

PLATE II.



CEPHALOSPORIUM SACCHARI.

time of planting, causes a good many of the young shoots to wither within the first 3 months. As this early withering has not been very frequently observed in natural attacks, we conclude that infection of the growing cane, through wounds and through the root buds at the nodes, is the more common origin of the disease.

The control of the disease should evidently be on much the same lines as in ture red rot*. As, however, wound infection is far more common, the importance of removing diseased clumps before they have time to rot and set free spores is much greater As a rule the disease is not a severe one and though our experience with it is limited as yet, it is probable that it is incapable of doing permanent damage so long as the measures advocated against red rot, which we consider to be essential to the successful growing of thick cane in Northern India, are carried out.

Description of Plate II.

(*Cephalosporium Sacchari* Butl.)

Fig. 1. Leaf of sugarcane inoculated with *Cephalosporium Sacchari*, showing fungus in the motor cells and emerging to the surface. × 640.

" 2. Hyphæ in parenchyma of stem and passing from cell to cell through the pits in the walls. × 190.

" 3. Hyphæ in fibro-vascular bundles. × 190.

" 4. Hypha in a cell of the parenchyma with indications of spore formation. × 320.

" 5. Spore formation on hyphæ in a vessel of the stem. × 320.

" 6. Mycelium bearing conidia, from a pure culture on nutrient agar. At *a* the commencement of the formation of a coremial strand is seen. × 320.

" 7. Conidiophores from a pure culture, after treatment with acetic acid. At *a* the adherence of the conidia at their bases is indicated. × 640.

" 8. Successive stages in conidial formation, drawn from a continuous observation. × 640.

" 9. Conidiophore immediately after a spore has fallen and before a new one has commenced to appear, showing the hollowed apex. × 640.

" 10. Conidia from nutrient agar culture, 6 days old. × 640.

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* Butler, E. J., & A. Hafiz Khan, *loc. cit.*

Fig 11 Germination of the conidia, showing especially the septation which sometimes precedes germination × 320.

, 12 Union of the germ tubes of the conidia. × 320

, 13 A spore bearing hypha continuously observed, showing the extent of growth and spore formation in 22 hours At *a* conidiophores have continued apical growth after forming a single conidium The septa have been omitted

II.—Collar Rot.

(*Hendersonina Sacchari*, Butl. n. g., n. sp.)

In the last section a disease was described which has frequently been mistaken for red rot. A second disease is sometimes confused with red rot in India, and the following description may lead to its recognition and thus secure further information regarding its distribution and the amount of injury it causes the crop, points on which our observations are incomplete.

Towards the end of 1908, a number of canes withered at the Samalkota Sugarcane Station, following on a cyclone at the end of September, which did much harm to the crop. A recrudescence of red rot was feared, as many of the canes were reddened at the base. We examined the crop in January, 1909, and found extremely little true red rot. Some of the damage was apparently not caused by disease but by injury to the root system as a result of the storm. A good many cases were seen, however, in which the symptoms suggested the action of a definite parasite at the base of the plant, and a fungus was isolated from the tissues in these cases which proved capable of reproducing the disease.

In the following season the disease reappeared and was more fully studied, but for the last three years there have been no further records of its occurrence on this farm. Recently it has been found at Jorhat Farm in Assam, and it is possible that it also exists in the Central Provinces, where we have observed a somewhat similar condition, but without being able to make a detailed examination. It has not been recorded elsewhere, and the parasite differs so widely from any previously known that it has been necessary to make it the type of a new genus. The varieties of cane so far observed to have been attacked are Red Mauritius, Striped Mauritius and B. 208.

The symptoms outwardly resemble those of red rot, so far as the withering of the top is concerned. The top leaves wither back from the tip along the edges, the midrib remaining green later than the rest of the leaf. The larger leaves below the crown appear to suffer first, those at the apex remaining unaffected for some time. When the leaves have fully withered, the cane is found to be much lighter than normal. On splitting, the upper part is usually pithy and dry in the centre, or even with a central cavity along each internode, around which the pith is dry, white and flaky. Lower down the pith may be still juicy but has a curious translucent watery appearance; still lower the centre portion may be brown, while red streaks or patches may often be seen, especially at the nodes (Pl. I, Fig. 2). At the base, where the feeding roots arise, the red colour predominates and is especially visible at the nodes. In old cases the lower internodes also dry up and may develop a central cavity, surrounded by red or brown pith. The roots arising from the basal nodes are usually blackened and rotten, and the appearance suggests that the disease enters the base of the stem from the roots.

In the Jorhat cases the buds at the lower nodes had sprouted and subsequently withered. The reddening was specially well developed at the nodes from which these shoots arose. It is not yet certain how far this sprouting of lateral buds is a symptom of the disease, as it appears possible that the Jorhat attack is complicated by the occurrence of a non-parasitic, *sereh*-like degeneration of the cane, which requires further investigation.

Microscopic examination shows that the roots and base of the stem are invaded by a fungus. The mycelium is confined to the definitely reddened parts, being absent from the translucent upper portion of the cane. In the Jorhat cases the fungus was found collected chiefly at the nodes, the intervening internodes being almost free from hyphæ until a late stage. The discoloured roots always contain a considerable quantity of mycelium. In the early stages the hyphæ run between the cells in the intercellular spaces. Here they are usually extremely fine, though thick ones sometimes occur. Later on, branches from the inter

cellular mycelium penetrate the walls to enter the cells. All the tissues are invaded, bundles as well as parenchyma (Pl. IV, Fig. 1) In the cells, and especially in the vessels, very thick hyphæ may occur, sometimes almost alone, sometimes intermingled with the fine filaments. Careful observation shows that both kinds belong to the same mycelium and can be found in direct continuation with one another. Sometimes a haustorium-like, branched mass, arising from thick hyphæ in an intercellular space, almost fills a cell. At first septation is rather scanty, but in the older hyphæ the septa lie very close together, the segments thus formed being often broader than they are long. No trace of spore-formation was found either in the tissues or on the surface of the diseased canes before their death.

Cultures of the fungus were obtained in the usual way, from the surface of the cane pith cut with a red-hot knife. The fungus grew well on ordinary nutrient agar, forming a dense superficial growth. The following description is from pure cultures on this medium.

The mycelium is white or faintly tinged yellow. The hyphæ (Pl. IV, Figs. 2 & 3) are very variable in size. The main branches are very thick, sometimes up to 15 μ in diameter, at first hyaline and sparingly septate, then pale yellowish and closely septate. Branching is copious and often rectangular. Very noticeable is the tendency of the older branches to give off extremely fine, hyaline, thin-walled hyphæ, the difference in diameter being so great as to suggest a distinct mycelium, until carefully examined. The thin hyphæ are often irregularly swollen or even nodular and measure sometimes as little as 1 μ in diameter. Anastomosis of neighbouring branches is not uncommon (Pl. IV, Fig. 3*a*). Intermediate stages, consisting of hyphæ 6 to 8 μ in diameter, freely septate when old and often irregularly swollen, are common. The thicker branches break up readily into chlamydospores (Pl. IV, Figs. 4 & 5), which may be terminal or intercalar, and are usually arranged in short chains. They consist of thick-walled cells filled with reserve material, round, oblong or long elliptical in shape, variable in size, the

largest up to 33 μ in diameter, at first hyaline but later slightly coloured. They frequently separate from the mycelium when mature, and may be found lying singly or in short chains intermingled with the hyphæ. They germinate in water by an outgrowth of the endospore. The nodular swellings on the smaller hyphæ seem to be of the same category, but do not usually become detached; they often give off fine branches after reaching maturity. In many cultures no other spore form was found. In several, however, a pycnidial stage developed, and this stage was subsequently found on the surface of old canes which had been killed by the disease.

When pycnidia were formed, they began to appear in about 3 weeks after sowing the tubes, as fine blackish dots immersed in the white mycelium. These grew to form prominent black nodules, which, under the microscope, were found to consist of stromatic tissue with one or more sporiferous loculi entirely immersed in the stroma.

The stromata are leathery, roundish-conical, about 1 to 2 mm. in diameter, and consist of an outer portion of brown, fibrous tissue, composed of closely woven hyphæ, and an inner, bounding the loculi, of dark brown pseudo-parenchyma, many layers deep. Sometimes bands of the fibrous tissue separate the loculi, each cavity then having its separate investment of pseudo parenchyma (Pl. III, Fig. 1), in others the whole centre portion of the stroma is cellular and the cavities have no distinct walls, except the lighter coloured layers from which the spore stalks arise. The cells of the pseudo-parenchyma are distinct, angular, isodiametric in the deeper layers, but becoming more elongated as the hymenium is approached, with unthickened but deeply pigmented walls and oily contents, and measuring up to 10 μ in diameter. The colour gradually becomes lighter towards the spore-bearing surface.

The pycnidial loculi are deeply sunken in the stroma, very irregular in shape, and often communicate with one another by narrow passages. Every stage may be found between stromata with a single loculus, through such cases as shown in Pl. III,

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H nlers mm S chm

Fig. 1, which we take to represent the union of several unilocular stromata, to truly multilocular pseudo-parenchymatous masses. The cavity is usually narrow, due to cushion-like projections of the wall into the lumen. In small unilocular stromata, the cushion arises usually at the base, the cavity being convex outwards. In larger stromata cushions may also project from the sides, leading to very irregular formations. In transverse section through the middle of the stroma (Pl. III, Fig. 3), the cavities are quite irregular in position, but near the apex the arrangement may be roughly circular, due probably to several loculi converging to a common opening. Laterally situated loculi may, however, open by separate orifices. In longitudinal section (Pl. III, Fig. 2), there is no uniformity of disposition or size of the cavities. The mouth is formed late and is usually not prominent.

The spores are of two kinds, both borne on exactly similar sporophores. The latter arise from the innermost layer of the pseudo-parenchyma, which is not sharply marked off as a hymenium but consists simply of small, rather elongated cells, light yellow in colour (Pl. IV, Fig. 6). From these one or more hyaline sporophores arise and project into the cavity. Usually the sporophore is branched, the branches arising chiefly near the base and each terminating in a single spore (Pl. IV, Figs. 7 & 8). In some stromata unbranched sporophores predominate (Pl. IV, Fig. 9). Septa occur sparingly and the ultimate branches are always slender and unseptate. Each sporophore appears always to bear only one kind of spore, but as they are closely crowded at the base, and both spore forms are found side by side in the same cavity, it is difficult to be certain on this point. Both kinds of spores appear to arise simultaneously.

The most highly differentiated spore form (Pl. V, Fig. 1), consists of brown, elongated cells, rounded at the ends, unicellular or with one or two transverse septa, usually straight but sometimes curved, the curvature in bicellular spores being occasionally sigmoid. They measure 15-24 × 3·75 to 5 μ. In some cultures unicellular spores predominated, in others bicellular. Three-celled spores are the least numerous. Germination occurs

in less than 24 hours by an outgrowth from one or both ends, the germ-tube remaining unseptate until it has reached a considerable length (Pl. V, Figs 4 & 5).

The other spore form (Pl. V, Fig. 2), consists of hyaline filamentous cells, usually without septa but with many oil drops, straight or irregularly curved, variable in length and breadth, the longest being often very narrow, sometimes broader at the base and tapering to a narrow apex, sometimes quite uniform in diameter. They measure 20 to 60 by ·6 to 2 μ. Germination was not observed.

An intermediate form of spore (Pl. V, Fig. 3) is sometimes found, consisting of pale yellow, elongated, 1-septate cells, borne on sporophores of the type above described and measuring 18 to 30 by 2 to 3·75 μ.

After the pycnidial stage had been obtained in pure cultures, it was found in two cases on old canes attacked by the disease, one being an inoculated cane at Pusa, the other a diseased cane from Jorhat. The stromata develop in the internodes, under the epidermis, or one or two layers deeper in, and are smaller than those obtained in culture. The outer fibrous layer is absent or reduced, the mass of the stroma being parenchymatous. The base is broad and extends for some distance all round, as a narrow stromatic layer between the tissue cells. In the centre, the epidermis is raised up and ruptured by the roughly conical, deep portion of the fruit body, which is hollowed out into one or several cavities. Unilocular stromata are common, the cavity being irregular or sometimes imperfectly divided by incomplete walls. The mouth is usually single and develops late. Both spore forms occur in the loculi.

There is much greater uniformity in the spore characters in any one culture of the fungus, than would appear from the above description, which is based on the examination of a large series. Thus, in some cases, the first spore form was almost entirely unseptate and small and the second broad and distinct; in others bicellular spores of the first type were chiefly found, intermingled with which were a few hyaline, attenuated spores of the second

type; in others again the narrowly filiform second type predominated, while there were numerous "intermediate" spores and only a few typical bicellular brown spores: finally in some cases, especially in the earlier cultures, all the types above described, except the "intermediate," were found, though 3-celled spores were never common.

Hence we have had some difficulty in deciding whether the fungus should be considered to belong to the sections *Phaeodidyma* or *Phaeophragmiae* of the *Sphaerioidaceae*. But the characters as a whole agree better with those of the latter section, of which *Hendersonia* is the main type, than with the former, which consists mainly of *Diplodia* and its allies, and the 3-celled brown spores should, we think, be considered as the most highly differentiated and, therefore, most important for systematic purposes. The genus differs from the rest of the *Phaeophragmiae* chiefly in the characters of the stroma and the possession of two distinct types of spore in the same loculus The latter peculiarity approaches it to the genus *Phomopsis* amongst the *Hyalosporae*, and it is of great interest as supporting the view that the hyaline, filamentous bodies of the latter genus are true spores, and not merely disjuncted basidia as has been maintained by some observers. There cannot be the smallest doubt that these bodies in the present fungus are spores, for they are borne on true sporophores, in an exactly similar fashion to the spores of the first type Another fungus in which two spore forms are found in the same pycnidium is *Fusicoccum viticolum* Red*., which Shear† has shown to be the imperfect form of *Cryptosporella viticola* Shear. Shear distinguishes the two spore forms as pycnospores and scolecospores, and believes the latter to be true spores, not basidia as held by Reddick. The pycnidia themselves are immersed in a stroma, which is evidently of much the same type as that of the sugarcane fungus.‡ It should be

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* Reddick, D. Necrosis of the grape vine, Cornell Univ. Agr Expt. Stat Bull 263, 1909.

† Shear, C. L. The ascogenous form of the fungus causing dead-arm of the grape Phytopathology, I, 1911, p. 116.

‡ Gregory, C J. A rot of grapes caused by *Cryptosporella viticola*. Phytopathology, III, 1913, p. 20, fig. 1.

noted that several species described as *Phomopsis* are multilocular stromatic*, though Diedicke, who has most fully studied the genus, places it amongst the simple forms, and does not seem to include any species with a multilocular stroma. Another genus which may be compared is *Endothiella* Sacc., where the bodies described as filiform basidia or pseudo-paraphyses are probably scolecospores.

The following is the diagnosis :—

Hendersonina Butl. nov. gen. *Sphæropsidacearum*—Stromata innato-erumpentia, atra, coriacea, parenchymatice contexta. Pycnidia (loculi) immersa, inæqualia, ostiolis sæpe confluentibus. Basidia ramosa. Sporulæ in basidiis acrogenæ, alteræ fuligineæ, ellipticæ vel elongatæ, rectæ vel curvulæ, continuæ vel 1-2 septatæ, alteræ hyalinæ, filiformes, rectæ vel flexuosæ, continuæ.

Hendersonina Sacchari Butl. n. sp. Stromatibus cortice innatis demum erumpentibus, subgloboso-conicis, 1-2 mm diam., atris, intus 1-pluri-locularibus; loculis irregularibus, subinde incompletis vel inter se communicantibus, ostiolis sæpe confluentibus; contextu brunneo, minute parenchymatico ; basidiis ramoso-fasciculatis, hyalinis ; sporulis dimorphis, aliis fuligineis, rectis vel curvulis, ellipsoideis vel elongatis, utrinque obtusis, continuis vel 1-2 septatis, 15-24 $\times$ 3·75-5 μ, aliis hyalinis, filiformis, rectis vel flexuosis, pluriguttulatis, 20-60 $\times$ ·6-2 μ.

In culmis *Sacchari officinarum* in India, or

As this fungus is possibly the lower stage of a Pyrenomycete, attempts were made to obtain an ascigerous stage in culture on organic media. The following were tried : —Potato, carrot, onion, plantain, *Colocasia* corm, fruit of *Carica Papaya*, fruit of *Psidium Guajava*, boiled rice, bread paste and sugarcane pith. The last medium was the only one, besides nutrient agar, in which pycnidial stromata were developed and none gave rise to

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* *c. f.* Harter, L. L. & Ethel C. Field. *Diaporthe*, the ascogenous form of sweet potato dry rot Phytopathology, II, 1912, p. 121. Roberts, J. W. A new fungus on the apple. *ib.*, p. 263.

an ascigerous stage. After a week the onion cultures were the best, followed closely by carrot, potato, *Carica*, *Colocasia*, *Psidium* and rice. On bread also the growth was good, while plantain and sugarcane were much inferior, especially the last. The mycelium was loose and had begun to lose its original white colour in many of the tubes, the upper part of the aerial mycelium (which exceeded 2 inches in height in some of the cultures) turning grey, except in the plantain, rice and sugarcane tubes, while the growth near the surface of the medium remained white in all. A submerged growth had developed in the water in the bottom of the (potato) tubes and this became light purple or pinkish in the carrot, onion and *Carica* tubes. The medium was discoloured dirty grey in the onion tubes, eye-grey to purple in those of rice and slaty-blue in those of bread. Five days later a blackish crust had developed on the surface of the water in the potato, carrot, onion, *Carica* and *Psidium* tubes, the submerged mycelium was light cinnamon colour in the onion and *Psidium* tubes, brick red in the plantain, and unchanged in the others. The colour had diffused into the water. The aerial growth was turning brown on the surface in the carrot, onion, plantain, *Colocasia*, *Carica*, *Psidium* and bread tubes, with a little pink in places in those of *Colocasia*. The medium was blackened in the potato, carrot and *Carica* tubes, while the upper part of the rice was dark coloured and a bluish line separated this from the unaltered lower portion ; the same bluish colour developed in the upper part of the bread paste. Seventeen days later there was little change, the growth in the potato and onion tubes was darker, that in the carrot, plantain, *Carica* and *Psidium* tubes had become pinkish in places, the submerged mycelium was chocolate-brown in the plantain, and chestnut in one of the sugarcane tubes, and a few dark dots were noticed in the denser parts of the mycelium of several tubes. These did not develop further and were ultimately found to be merely condensations of sterile mycelium.

The following inoculations were carried out with pure cultures, obtained as above described.

In October, 1909, 35 canes in a plot of strong healthy Red Mauritius, about 7 months old, were inoculated at Samalkota by removing a cylinder, about half an inch in length, with a small, flamed cork borer and inserting a small tuft of mycelium. The cylinder was replaced after cutting a little off the end, and the wounded stem bound with sterile gutta percha sheeting. Seven weeks later, two of the inoculated canes commenced to wither. In January, 1910, another inoculated cane withered and was sent to Pusa for examination The condition of the stem was similar to that in the canes from which the fungus was first obtained. The inoculated internode was bright red. The reddening extended upwards for 3 internodes, the 3rd having only one bright red bundle. Higher up, the translucent, watery condition of the pith, already described, was found. Downwards, the reddening extended for 2 internodes. Hyphæ were numerous in the reddened parts and pure cultures of the fungus used in inoculating were obtained readily. In February, four more of the withering inoculated canes were received, as well as two non inoculated canes arising from the same clumps, which seemed to have become infected secondarily. The inoculated canes had typical symptoms. In two, the infection had extended downwards to the base of the stool, the upper part being less affected. In the other two, distinct reddening occurred for 2 or 3 internodes above the wound and the pith was translucent and hollow in the centre for some 10 internodes higher. The hyphæ were, as usual, confined to the reddened portion, where they were plentiful and easily obtained in pure culture, giving rise to the same fungus used in inoculating. The two non-inoculated canes had become infected from below ground, apparently through the roots, and were withering as a result of the attack. The fungus was recovered from these canes also. Early in March the plot was inspected by one of us (E. J. B.). A number of the inoculated canes had withered and the disease had extended in some cases to other canes in the same clumps. The rest of the plot was quite free from disease, except where the second series of inoculations, to be described below, was located. The symptoms were typical and left no doubt of the success of the inoculations.

On the same date as the last, a second series of inoculations was carried out in the same plot, by removing the soil from around the base of four clumps of cane and watering the exposed roots with a suspension of the mycelium beaten up in water. These also took well, and when seen early in March each clump had one or more withered canes. No other canes were withering in the rest of the row to which the clumps belonged nor, so far as could be observed, in any part of the plot, except the row in which the first series of inoculations had been made. One cane from each clump was split and found to have typical symptoms of the disease, but there was no opportunity for microscopic examination. The symptoms were, however, so definite that there was no doubt that this series was quite as successful as the first

As the disease does not occur at Pusa, it was not considered advisable to carry out any inoculations in the field. Some were, however, made on plants growing in tubs, at a distance from the farm crop. The number of canes inoculated through stem wounds was six, growing in four tubs, one tub being kept as a control The inoculations were made in November 1909, exactly in the same manner as those of the first series at Samalkota. In the following March none of the inoculated canes had withered and two were removed for examination. The inoculated internode was found diseased in both, the mycelium being confined to the one internode in one case but extending to the next higher up in the other The other plants were kept in the tubs until the following year, by which time they were still alive but had ceased growth, except for a few feeble side shoots. In May 1911, they were cut and examined. The inoculated canes were much reddened near the wound, the reddening extending for from 2 to 4 internodes each way. Above the reddened part, the characteristic translucent appearance and internodal hollowing of the pith was found. The red parts were full of the hyphæ of the parasite and, in one case, pycnidial stromata had developed in the internode next below that inoculated. The roots were not affected and no spread to other shoots in the same stool had occurred. The parasitism was, therefore, much less marked than at Samalkota, though the spread of the

mycelium in the living tissues indicates a certain degree of parasitic activity.

In three other tubs, the main canes of which had been injured and in which a "ratoon" crop was growing, inoculations similar to those of the second series at Samalkota, were made in December 1909, the exposed roots being watered with a suspension of the fungus. No outward sign of disease appeared, and the following April the stools were uprooted, as also that in the control tub. All were found perfectly healthy and no trace of the parasite could be detected in the tissues.

It seems probable, therefore, that the disease is restricted in its distribution by climatic or other unknown conditions, as so many of the fungus blights of crops in India are. How much damage is caused by it is unknown. Both at Samalkota and Jorhat it was enough to cause uneasiness, but in the latter case it is still uncertain whether there are not two diseases at work. If it should be found that the condition observed at Jorhat, in the Central Provinces, and elsewhere, of excessive tillering, combined with degeneration of the plant, sometimes to such an extent that no true canes at all are formed, the whole plant remaining grass-like, is caused by this parasite, then it will have to be reckoned as a serious disease. Meanwhile, further investigations are in progress and it is hoped that the publication of the present description will lead to the recognition of the disease, where it occurs, and fuller observations on its field characters. It is obviously impossible, at present, to suggest methods for its check beyond the ordinary precautions urged on previous occasions for routine observance in sugarcane cultivation in India.

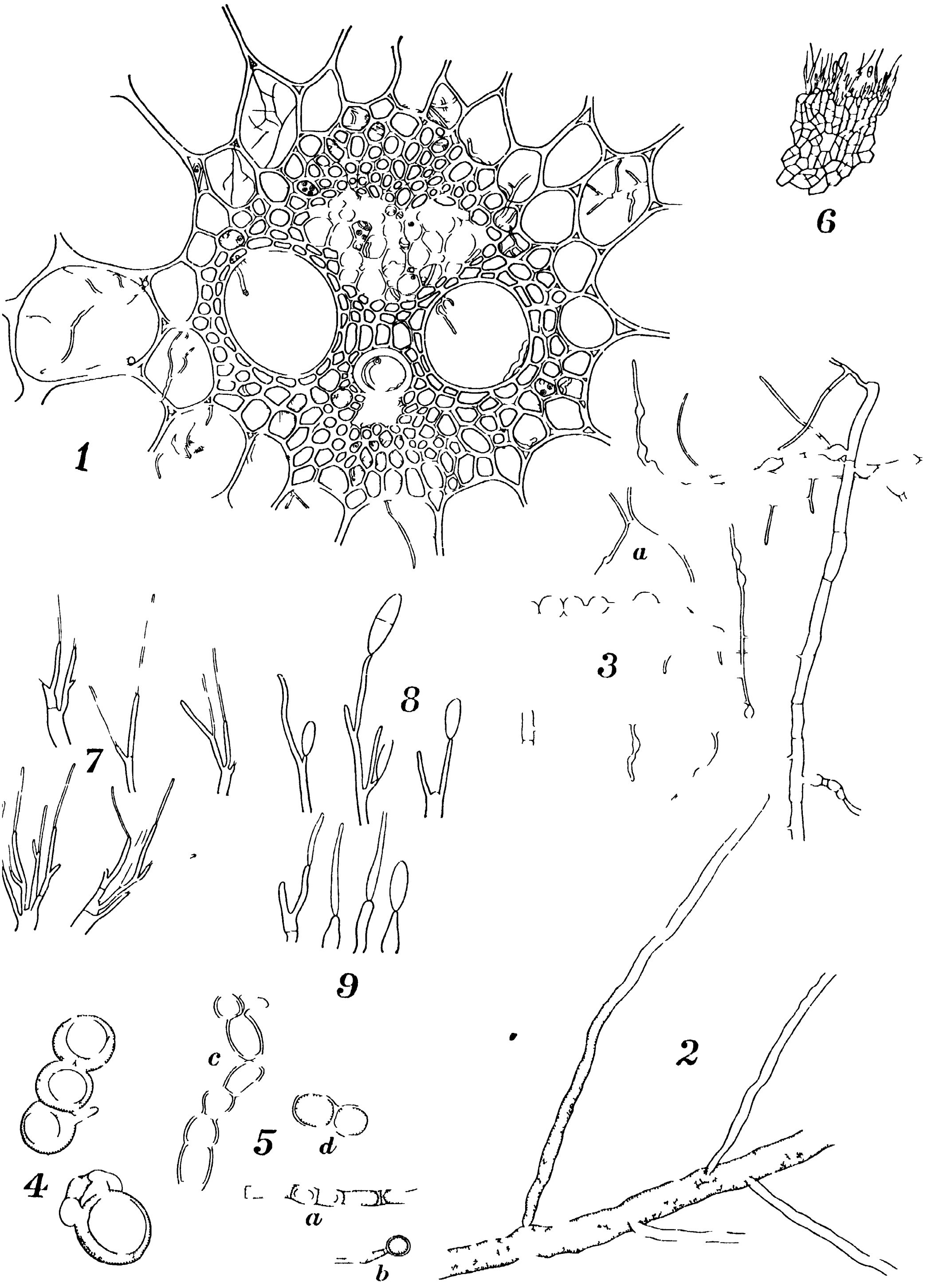
DESCRIPTION OF PLATES III, IV AND V.

(*Hendersonina Sacchari*, Butl.)

PLATE III.

Fig. 1. Section of a sclerotium of *Hendersonina Sacchari*, probably formed by the union of several unilocular stromata. Each cavity is surrounded by a separate pseudo-parenchymatous wall, between which the structure is filamentous. A mass of spores of both types is extruding from the mouth of the left-hand cavity.

PLATE IV.



HENDERSONINA SACCHARI

Hendersonina Sacchari.

Fig. 2. Ripe sclerotium in longitudinal section, showing the irregular loculi, immersed in a pseudo-parenchymatous stroma. The cavities were filled with spores, which are not shown.

" 3. Another ripe sclerotium in transverse section. At the base, this sclerotium showed only two large loculi. Near the apex there were seven cavities, arranged roughly in a ring and mostly opening by a common mouth.

PLATE IV.

Fig 1. Transverse section of part of the pith of a cane, infected by *Hendersonina Sacchari*. The hyphæ grow from the intercellular spaces into the cell cavities. Intermediate and fine hyphæ are present, but not the very thick kind. X 190.

" 2. Very thick hypha from the surface growth obtained on incubating an inoculated cane. Branches of intermediate diameter are numerous. These in turn will give off very fine threads. Septation has not yet occurred. X 350.

" 3. Mycelium from a culture, showing fine and intermediate hyphæ and chlamydospores. The fine branches are irregularly swollen, and at *a*, two have anastomosed by a side branch. Later stage of growth than Fig. 2. X 350.

" 4. Chlamydospores separated from the mycelium and germinating. X 500.

" 5. Formation of chlamydospores. *a* early stage, intercalar; *b* ditto, terminal; *c* a chain separating from the mycelium (one is germinating). *d* old chlamydospores from a chain, that on the right has lost part of its exospore. X 350.

" 6. Part of the wall of a pycnidium, showing the abrupt transition from the sclerotial cell layers to the basidial layer.

" 7. Basidia with filamentous spores (scolecospores). X 625.

" 8. Basidia with the broad type of spore (pycnospore). X 625.

" 9. Simple types of basidium, the 3 on the left with hyaline scolecospores of a broader type than usual, that on the right with a young pycnospore. X 625.

PLATE V.

Fig. 1. Pycnospores of *Hendersonina Sacchari*. X 520.

" 2. Scolecospores of ditto. Some stromata contain only the narrow type, uniform in diameter shown at *a a*, others the more irregular forms. X 520.

" 3. Intermediate type of spore between the pycnospore and scolecospore types. X 520.

" 4. Germination of the pycnospores, early stages (24 hours after sowing). X 520.

" 5 Ditto, later stages (48 hours after sowing). X 520.

III.—HELMINTHOSPORIOSE

(*Helminthosporium Sacchari* Butl. n. sp.).

A species of this well-known genus, many members of which are parasitic on *Gramineæ*, is common on the leaves of sugarcane at Pusa. The infected leaves first show small red spots, which spread rapidly, chiefly in a longitudinal direction and especially towards the tip of the leaf, may run together to form long streaks The centre of the spot soon changes to a dirty straw colour, around which the margin remains red for a time and then changes to dark brown The spots occur equally on the midrib, where they may be confused with those caused by the leaf form of *Colletotrichum falcatum*,[1] and on the thinner part of the leaf When numerous, they cause death of the leaf tissues beyond the limits of the spots, the tip of the leaf often withers completely and there may be long withered strips down the margins.

The mycelium of the parasite is found in the leaf cells of the spotted portion and also collects in small stromatic masses on the surface of the spot The hyphæ are brown at the surface and in the outer cell layers, but hyaline deeper in They pass from cell to cell through narrow cracks in the walls (Pl VI, Fig. 2), which are especially noticeable in the thick-walled sclerenchyma which overlies the bundles, but within the cells are swollen so as almost to fill the cavity in the smaller cells. In the epidermis they frequently form small stromatic masses. The cells appear to be killed in advance of the growth of the fungus, as although the hyphæ are numerous in the dead cells, it is rare to find penetration of a still living cell

As soon as the centre of the spot begins to turn straw-coloured, fructification occurs by the growth of sporophores from

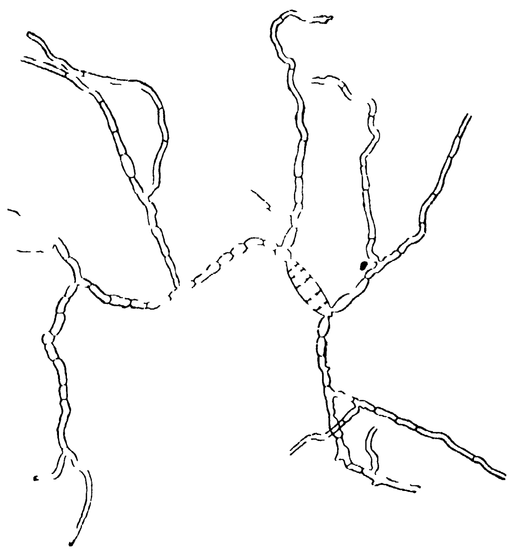
[1] Butler E. J. & A. Hafiz Khan. Red Rot of Sugarcane. Mem. Dept. of Agric. in India, Bot Ser., VI No. 5, 1913

the stromata, both those within the epidermal cells and those on the surface of the leaf.

The sporophores are stout, erect, rather rigid hyphæ, which arise from the peripheral cells of the stromata (Pl. VI, Fig. 4) They are usually unbranched, 3 to 10 septate, dark greenish-brown below, paler above and several times bent or "geniculate." Spores are produced at each bend and at the apex, the lowest being the first formed and the bent condition being due to the spores being always apical at first and being then pushed to one side by continued growth of the sporophore from just below the insertion of the spore. The sporophores are 100 to 190 μ long, by 5·5 to 7·5 μ broad.

The spores (Pl. VI, Fig. 5) are borne singly and readily fall off. They are cylindrical or long elliptical in shape, with very thick walls, and divided into from 4 to 11 compartments by broad partitions. The colour varies from olive green to brown and the size from 35 to 60 μ long, by 8·5 to 12 μ broad.

Germination occurs rapidly (within 3 hours in some cases) by the protrusion of a germ-tube from each end of the spore At the same time the internal partitions sometimes break down in the centre (Pl. VI, Fig. 6). Part of the mycelium formed from a single spore culture in a hanging drop, is shown in the text figure.



K. D. Das Cop

drawn 48 hours after sowing. The fungus can be readily cultivated on most ordinary media, but the spores formed in culture are usually smaller than those from the host plant. The following inoculations were made with pure cultures on nutrient agar.

In January 1909, 8 leaves of growing sugarcane were inoculated on the upper surface with a suspension of spores and mycelium, a drop of which was placed on each leaf and covered with damp, sterile cotton-wool. The leaf was not injured in any way. After 6 days, 3 of the inoculations were found to have succeeded, a red spot developing at the inoculated point and eventually giving rise to a typical infection. The other 5 and the controls showed no change. A second series was made at the same time on young healthy shoots brought into the laboratory. On these 6 inoculations were made, 3 being kept damp with cotton-wool and 3 by covering with bell-jars. The latter showed evident signs of infection in 2 days, but only 1 of the former succeeded and the spot was not visible until the fourth day. A month later 9 more inoculations were made on healthy shoots kept under bell-jars, all of which succeeded. One showed reddening in 24 hours, 4 more were visible in 3 days, and all were well marked in 5 days. A little later, 21 more inoculations were made in a similar manner to those of the last series. All succeeded well.

The microscopic examination of the inoculated leaves showed that penetration occurred directly into the epidermal cells (Pl. VI, Fig. 3). The infecting hypha swells up slightly in close contact with the cuticle and a narrow tube arises from the swollen portion and pierces the wall. As soon as the cell cavity is entered, the hypha swells up again and becomes freely septate, often forming a small mass of pseudo-parenchymatous cells. From this, branches pass to the deeper cells, and others approach the surface to form new stromata. The pressure exerted by these epidermal stromata is sometimes enough to rupture the outer wall before reproduction begins. The fructifications are usually confined to the quite dead central part of the spot.

The species does not seem to agree with any of those previously described. About 30 are known on various grasses, but none on *Saccharum*. The diagnosis is as follows :—

Helminthosporium Sacchari Butl. n. sp. Maculis amphigenis, elongatis, initio rubris, dein avellaneis vel stramineis ac ferrugineo-marginatis, 3-25 \/ 2-6 mm; cæspitulis minutis, atris; hyphis fertilibus erectis, simplicibus, 3-10—septatis, geniculatis, olivaceo-brunneis, apice pallidioribus, 100-190 \/ 5·5-7·5 μ; conidiis acrogenis, cylindraceis vel oblongo-ellipticis, utrinque rotundatis, 3-10-septatis, crassissime tunicatis, olivaceo-brunneis, 35-60 \/ 8·5-12 μ.

In foliis *Sacchari officinarum* in India, or

A fungus which, from the published descriptions, bears a considerable resemblance to the above, is known in Java and Hawaii under the name of *Cercospora Sacchari*, Br. de Haan. It was first described by Breda de Haan in Java,* as the cause of a leaf disease to which the name "eye spot" was given. A further account was subsequently published by Dickhoff and Hein†. In Hawaii it has been briefly described by Cobb‡. From the figures published in Wakker and Went's well-known text-book of sugarcane diseases§, it appears probable that this fungus is really a *Helminthosporium* and not a *Cercospora*. A comparison of the two fungi has not been possible and could alone settle the question of their identity.

Little requires to be said regarding the treatment as, so far, this disease has not been found to damage the crop materially. If it became severe, it would be advisable to strip off and destroy the affected leaves in the early stages of the attack (we have found the first spots in June, at Pusa). There are a good many

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* Breda de Haan, J. Van. Rood Rot en andere Ziekten in het Suikerriet. Meded van het Proefstation West Java, XVI, 1892.

† Dickhoff, W G. & S A Arendsen Hein Eenige Waarnemingen omtrent de Oogvlekkenziekte. Archief Java Suikerindustrie, IX, 1901, p 865.

‡ Cobb, N A Fungus Maladies of the Sugarcane. Exper. Stat of the Hawaiian Sugar Planters' Association, Division of Pathology and Physiology, Bull. No. 6, 1909, p. 36.

§ Wakker, J. H & F A F. C Went. De Ziekten van het Suikerriet op Java. Leiden. 1898, Pl XXI, figs. 1—5.

leaf diseases of sugarcane, but they cause little loss as a rule and, even in more advanced countries than India, do not seem to require treatment.

PUSA,
August 5th, 1913.

DESCRIPTION OF PLATE VI.

(*Helminthosporium Sacchari* Butl.)

Fig. 1. Section through leaf of sugarcane, showing hyphæ of *Helminthosporium Sacchari* in the outer cells. X 350.

,, 2. Part of a similar section, to show passage of the hyphæ from cell to cell. X 500.

,, 3. Infection of upper surface of leaf, from an inoculation, showing penetration of the outer wall of the epidermis and formation of small stromatic masses in the epidermal cells. X 930.

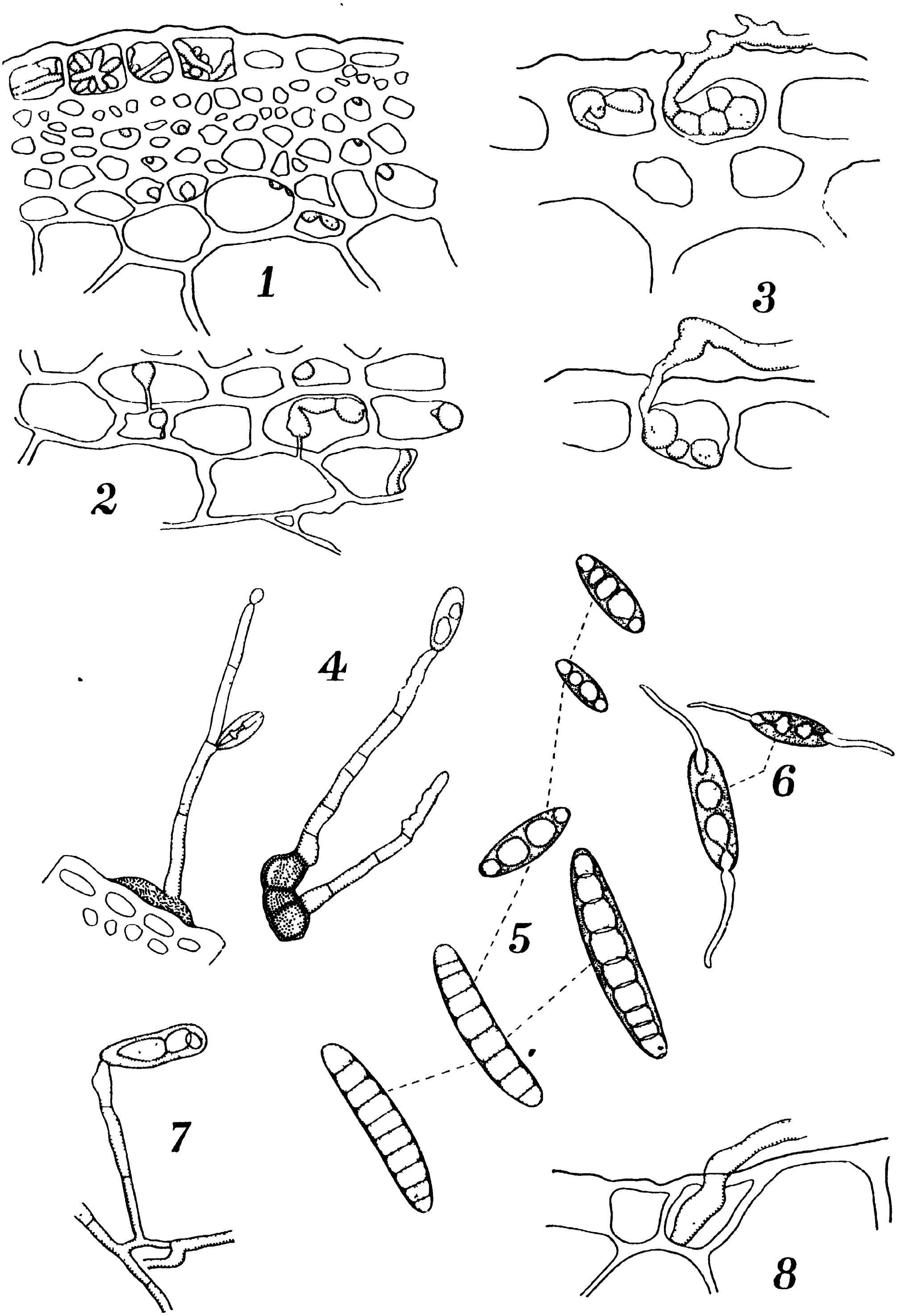
,, 4. Conidiophores with young conidia. X 350.

,, 5. Conidia. The three upper immature, the three lower mature. X 500

,, 6. Germination of the conidia. X 500.

,, 7. Reduced conidiophore and conidium, from a pure culture. X 350.

,, 8. Base of conidiophore, arising from within the epidermis and emerging across the cell wall, not through a stoma. X 500.



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HELMINTHOSPORIUM SACCHARI.

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

OROBANCHE AS A PARASITE IN BIHAR

BY

F. J. F. SHAW, D.Sc. (Lond.), A.R.C.S., F.L.S

Second Imperial Mycologist

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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OROBANCHE AS A PARASITE IN BIHAR.

BY

F. J. F. SHAW, D. Sc. (Lond.), A.R.C.S., F.L.S.,
Second Imperial Mycologist.

(Received for publication on 21st March, 1917.)

I. SYSTEMATIC.

In view of the fact that "tokras" are so widespread in Bihar, and occur on so many different hosts, the present research was commenced to investigate the biology of these parasites and in the hope of discovering whether any method could be devised to lessen the damage which they cause.

As is well known the parasitic species of *Orobanche*, known locally as "tokras," are small yellow plants from 3-12 inches high with bluish flowers. The stems are thick and succulent and the leaves are reduced to small scales, as is usual in plants of this habit. A very brief experience of this parasite in the field is sufficient to convince one that there are at least two species, which are common in Bihar. Hooker[1] describes eleven species in India, of which the greater number occur in the Himalaya and only three appear to be common in the plains; these are *O. indica* Ham., *O. cernua* Lœffl., and *O. Nicotianæ* Wight, the last named is stated to be a common and destructive pest of tobacco in the Deccan, while *O. indica* is said to be especially common in mustard throughout the plains of India. Prain[2] mentions two species, *O. indica* Ham. and *O. cernua* Lœffl., as being present in Bihar; he states that *O. cernua* is rare, and occurs on *Brassicas*, and that *O. indica* is the common pest of mustard, tobacco, *Brassicas*, etc. The presence of two bracteoles to each flower, and the fact that in *O. indica* the flowers are larger and not so closely crowded together as in *O. cernua*, are the distinguishing characters between the two species (Plate I, figs. 1 and 2; Plate II, fig. 3.).

The results of the observations recorded in the present paper differ somewhat from the facts given by Prain, and coincide more nearly with

[1] Hooker, *Flora of British India*, Vol. IV, 1885.
[2] Prain, *Bengal Plants*, 1903.

the statements of Hooker. The two species of *Orobanche* in Bihar are as follows :—

(1) *O. indica* Ham. Flowers with two bracteoles, calyx four—rarely five-toothed, divided to the base posteriorly, entire anteriorly, spikes loose flowered, corolla large, blue, stem often branched. This form belongs to the section of the genus named *Trionychon* Wallr. and is probably identical with *O. ægyptiaca* Pers. (*vide* Beck von Mannagetta[1]), and very closely related to, if not identical with, *O. ramosa* L.[2]; this latter name is given by Massee[3] as that of a species which is parasitic upon tomato in England. In Bihar *O. indica* is the form which is the common and destructive parasite of mustard, cabbages, turnips, etc. It occurs on tobacco and tomato but does not appear to be, as a general rule, as serious a parasite of solanaceous crops as is *O. cernua*.

(2) *O. cernua* Lœffl. Bracteoles not present, calyx divided to the base posteriorly and anteriorly, lobes of th calyx bifid, spikes dense, corolla smaller and paler in colour than in *O. indica*, stem usually unbranched and thicker than in *O. indica*, frequently showing fasciation. This species belongs to the section *Osproleon* Wallr. of the genus *Orobanche*, and is stated by Beck von Mannagetta to be identical with *O. Nicotianæ* Wight. Hooker, however, distinguishes between these two species and states that *O. Nicotianæ* differs from *O. cernua* in the fact that the bract in the former is as long as the corolla tube and the lobes of the calyx are entire, and not divided. Prain makes no mention of the species *O. Nicotianæ*, which, according to Hooker, is restricted to the Deccan, and we have not seen any undoubted specimens although some specimens of *O. cernua* have closely approached to it when the lobes of the calyx were only slightly divided and the bract was rather larger than usual.

The species *O. cernua* is the common parasite of solanaceous crops in Bihar but does not appear to attack *Cruciferæ* (*cf.* Prain), only in four specimens were plants of *O. cernua* found on mustard. The parasitism of this species is therefore more restricted than is that of *O. indica*, which, while being a serious parasite on *Cruciferæ*, does occur to a certain extent on *Solanaceæ*. The life-histories of the two species appear to be identical, the "tokras" appearing a few weeks after the host crop is well established and rising to flower and fruit along with it. On mustard *O. indica* is sometimes a good deal earlier than on other crops, flowering from the beginning of December to the beginning of February, while *O. cernua* on tobacco is distinctly later, but there is a good

[1] Beck von Mannagetta, G. R., "Monographie der gattung Orobanche," *Biblioth Botan* Heft. 19. Cassel, 1890

[2] Hooker, p. 326 *loc cit.*, page 107.

[3] Massee, G., *Diseases of Cultivated Plants and Trees*, 1910

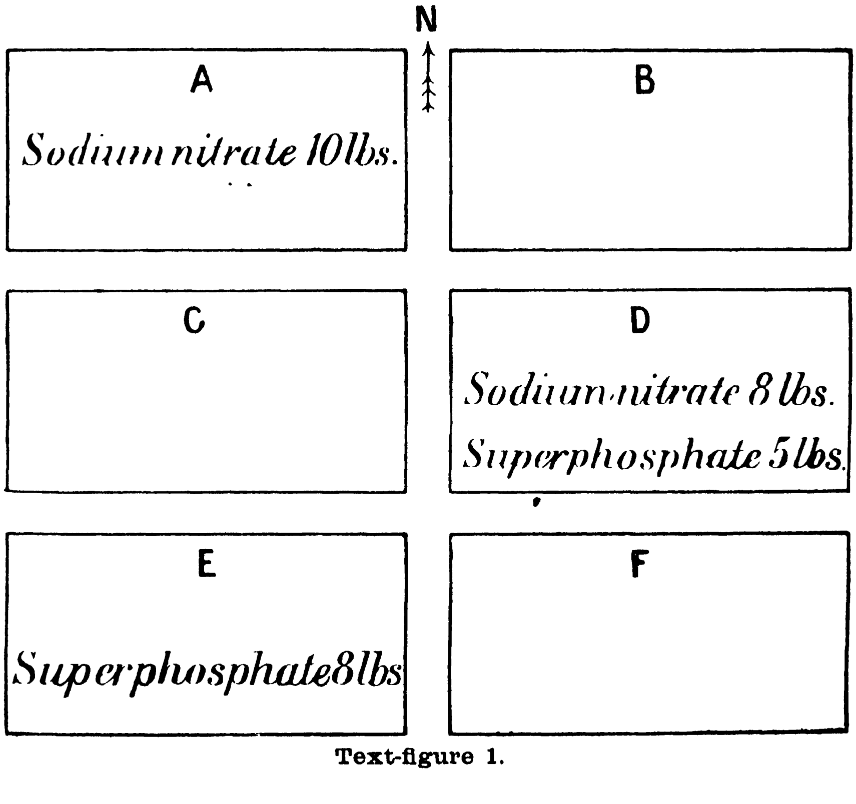
deal of variation in this matter from one season to another. Both species rely on the production of countless millions of minute seeds for their dissemination and perennation. These seeds are present all over the cultivated lands of Bihar, their number and minute size being extremely favourable to their dispersal in the strong winds which often prevail in February and March when the fruits of *Orobanche* are ripe.

The universal distribution of this parasite and the severity of the damage caused to a valuable crop, such as tobacco, make any practical remedial measures an important factor in Bihar agriculture. The field experiments described in this paper were devised with a view to testing whether the claim, which had recently been advanced, that Chili saltpetre (sodium nitrate) was a specific against "tokras" was founded upon fact.

II. FIELD EXPERIMENTS.

(1) Pusa—Season 1914-15.

A piece of land in the kitchen garden which had been under vegetables (cabbage, cauliflower, potatoes) for some years, and was known to be badly



Text-figure 1.

infected with "tokras." was selected for experimental work. This area was divided up into six equal plots (A, B, C, D, E, F), each about $\frac{1}{20}$th acre, and chemical manures were applied as indicated on the plan (Text-figure 1).

On the 6th October, 1914, the manure was spread evenly on the surface of the soil and mixed with the soil with a khurpi, a light beam harrow was then run over the surface. Tobacco (*Nicotiana tabacum*) was planted out in all the plots during the following fortnight.

In spite of the fact that the land was known to be badly infected with "tokra," a fair crop of tobacco was obtained and there were very few "tokras." Both *O. indica* and *O. cernua* occurred, but their incidence did not appear to be in any way affected by the application of the manures. The total number of "tokras" in the tobacco was about twenty, although in the previous year when the land was under cabbages they were to be counted by the thousand. The "tokras" which occurred on the cabbages were, of course, *O. indica*, the common "tokra" of *Brassicas*, and the explanation of the relative immunity of the tobacco, during this first season, seemed to be that this species was not a serious parasite of tobacco. This coincided with observations in the fields round Pusa where although *O. cernua* usually prevailed on the tobacco, a certain amount of *O. indica* could nearly always be found.

(2) Pusa Season 1915-16.

The same land was placed under tobacco, mustard and cabbage as indicated in the Text-figure 2. (See p. 111.)

(*a*) *Tobacco.* The two northern plots (A and B) were planted with tobacco (*N. tabacum*); each plot contained 18 rows with 16 plants in each row. Of the two plots under tobacco the one on the western side (A) was manured with sodium nitrate. Instead, however, of mixing the nitrate with the soil before planting out, the manure was dissolved in water and given to each plant in solution. Each tobacco plant received 1 oz. of sodium nitrate, given in three doses at intervals of 7 days, during the later portion of November; in all about 18 lb. of sodium nitrate was distributed among 288 tobacco plants in an area of $\frac{1}{20}$th acre. This works out at a rate of about 3 cwt. per acre. The first "tokra" appeared in the unmanured plot in December, but by the middle of January plants were appearing in both plots. The tobacco was cut on March 13th and the amount of "tokra" counted with the following results :-

		Number of tobacco plants	Number of *O. indica*	Number of *O. cernua*
Manured (A)	..	288	70	185
Unmanured (B)	..	288	2	1,156

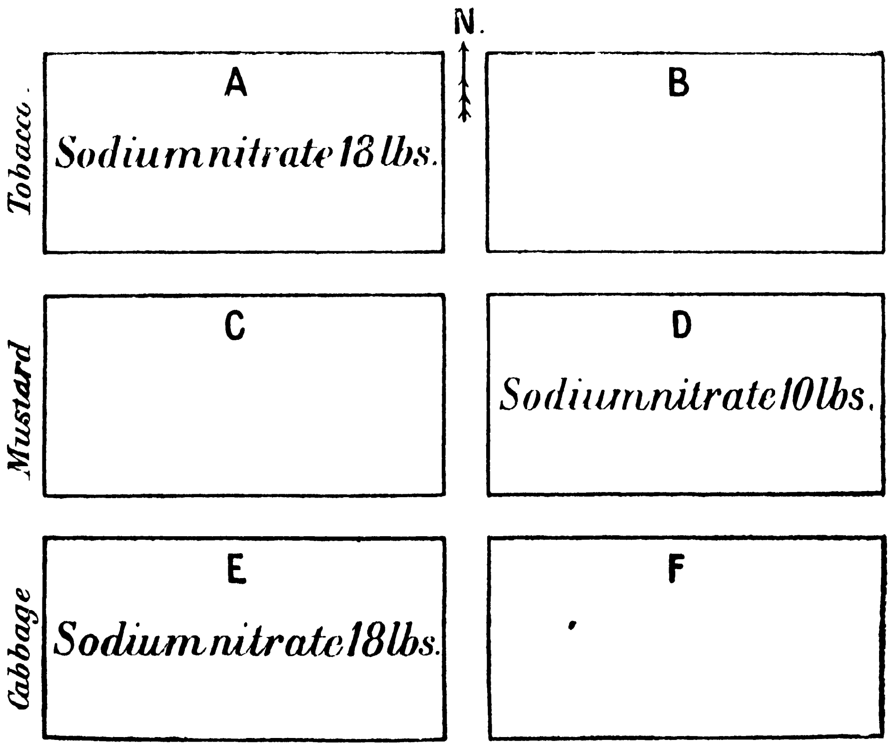
These figures bring out several facts :—

(1) The total amount of "tokra" in the second year was very much greater than in the first, the increase being particularly marked in *O. cernua*, which constituted 91 per cent. of the total number of "tokras" present.

(2) The bulk of the *O. indica* was concentrated in the manured plot and the bulk of the *O. cernua* in the unmanured plot; in the latter case the bulk of the *O. cernua* was on the eastern edge.

(3) The total amount of *O. indica* was very much less than was known to be in the soil but showed a substantial increase on the amount present in the previous years.

(4) The amount of "tokra" in the manured plot was only about one-fifth of that in the unmanured plot.



Text-figure 2.

With regard to the increase in the total amount of "tokra," this increase is really larger than appears from the figures since the area under tobacco in the second year was only one-third of that under tobacco in the first year, the

remaining plots being used for mustard and cabbage. This increase consisting as it does principally of *O. cernua* is to be attributed to the seeds from last year's "tokras," which fell into the soil as the fruits ripened and germinated next season with the second crop.

Although it was evident, from an inspection of the numbers of "tokras" in the neighbouring plots of mustard and cabbage, that large quantities of the seed of *O. indica* were in the soil yet in proportion very few plants of *O. indica* occurred in the tobacco. This bears out the conclusion of the previous season that this species is not normally a heavy parasite of tobacco. Yet a field of tobacco was found near Pusa in which the crop had been very severely damaged by *O. indica* -there being hardly any *O. cernua* present. These facts must be considered later when describing the results of the pot cultures.

The fact that the bulk of the *O. cernua* was in one corner of the unmanured plot, and the bulk of the *O. indica* was scattered over the manured plot, cannot but suggest that the degree of local infection in a particular field is a very potent factor in the number and distribution of the "tokras" which appear and that the differences between the two plots in this experiment might be due to some factor other than the application of nitrate.

(*b*) *Mustard* (*Brassica campestris* var. *glauca*). Of the two plots under mustard that on the east (Plot D), received 10 lb. of sodium nitrate scattered on the surface and mixed with the soil immediately before sowing. The germination was good and the crop came into flower on 21th November, the first "tokra" showing above the surface about the same time in both the manured and the unmanured plot. From the end of November onwards there was a steady appearance of "tokra," all of which was *O. indica*. On February 12th the mustard was cut and the number of mustard plants and "tokras" in each plot was counted, the results were as follows:

		Number of mustard plants	Number of *O. indica*
Manured (D)	..	1,949	2,012
Unmanured (C)	..	1,631	3,070

The weight of the mustard cut from each plot amounted to about 8½ maunds. From the above figures it cannot be contended that the sodium nitrate had any very marked effect on the appearance of the "tokras," while the number of "tokras" which came up showed that their non-appearance in the previous season, when the plots were under tobacco, was not due to lack of infection in the soil but rather to lack of a suitable host.

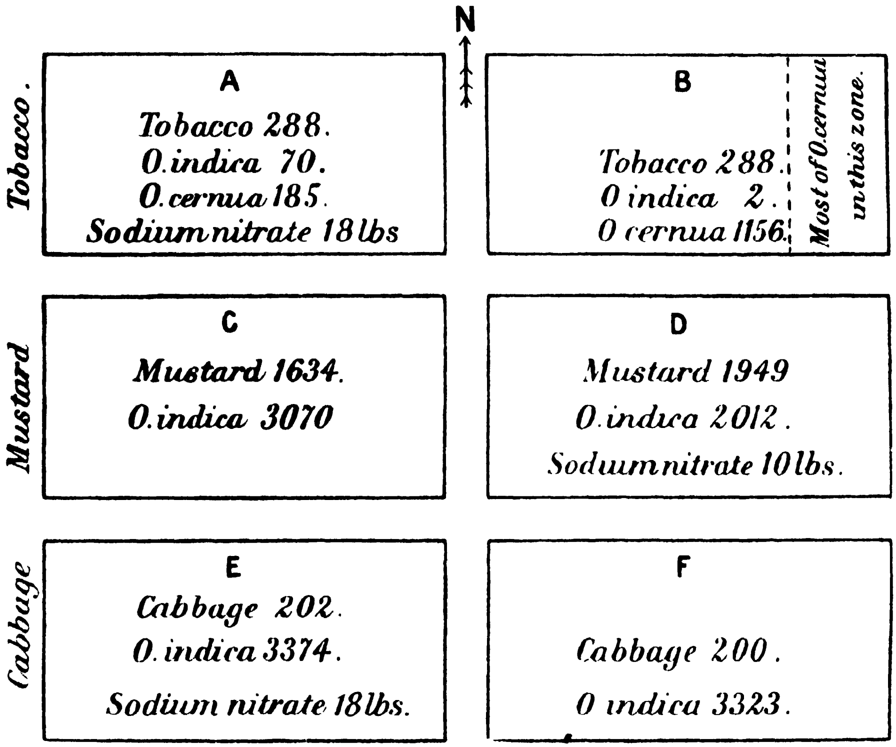
(*c*) *Cabbage* (*Brassica oleracea*). Cabbage seedlings were planted out in two of the plots towards the end of November. There were 200 seedlings

in each plot and one plot (E) received 18½ lb. of sodium nitrate. The nitrate was given to the plants in solution, each plant receiving about 1·4 oz., in three doses at intervals of six days. The cabbages grew well and there was a steady appearance of "tokra." In March the crop was counted and the figures were –

		Number of cabbages	Number of *O. indica*
Manured (E)	..	202	3,371
Unmanured (F)	..	200	3,323

Sodium nitrate did not have any effect on the "tokra."

The following Text-figure 3 is a diagrammatic summary of the second year's experiments : –



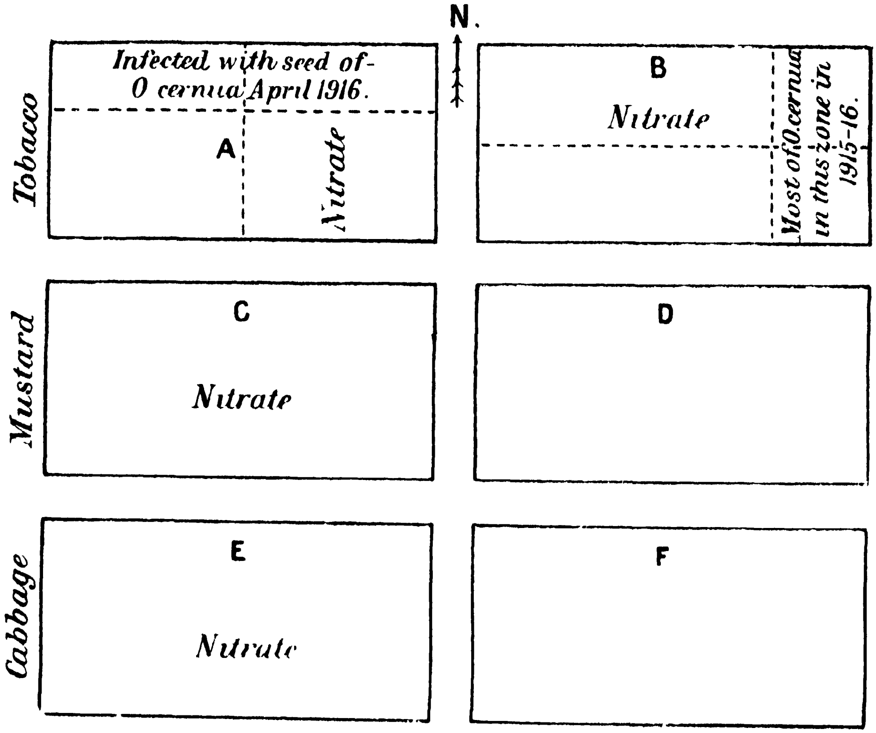
Text-figure 3.

(3) Pusa—Season 1916-17.

The same plots were placed under tobacco, mustard and cabbage as in the previous season.

(*a*) *Tobacco.* Of the two tobacco plots, that which had not received any nitrate in the previous season, 1915-16 (Plot B), had contained the larger

quantity of *O. cernua* and the bulk of this had been concentrated in a strip along the eastern edge of the plot. In April 1916, about 4 oz. of seed of *O. cernua* was collected from this plot and scattered along the northern side of the other plot, for about one-third of the breadth of the plot, a light beam was then run over the plot. In September, 1916, both plots were planted out with tobacco ; there were 18 rows with 16 plants in each row, making a total of 288 plants in each plot. Instead of manuring the whole of one plot, the eastern half of the western plot (A) and the northern half of the eastern plot (B) received sodium nitrate. The nitrate was given in solution in three doses, as in the previous year, and each plant manured received a total of 1 oz. of nitrate. Thus in each manured area 9 lb. of sodium nitrate was distributed among 144 tobacco plants. The scheme of the experiment in 1916-17 is shown in Text-figure 4.



Text-figure 4.

The effect of the nitrate upon the tobacco was especially marked in the case of eastern plot (B). This plot in the experiments of the two previous seasons had not received any nitrate and the tobacco in the manured half

of this plot was distinctly greener and larger than in the remaining portion. This difference was not observed in the western tobacco plot (A), which had been manured in the two previous seasons.

The tobacco was cut and the "tokras" counted on 2nd March with the following results:—

Eastern plot (B).

	Number of tobacco plants	Number of *O. indica*	Number of *O. cernua*
Manured	144	5	2,192
Unmanured	144	0	4,615

Western plot (A).

Manured	144	1	1,715
Unmanured	144	4	2,994

It was interesting to observe that in the eastern plot (B), in both manured and unmanured areas, the "tokra" was most plentiful in the eastern half, in which it had been the more abundant in the previous season. In the western plot it was most abundant in the northern portion of the plot which had been infected with seed of *O. cernua* in the previous April. The amount of *O. indica* in both plots was considerably less than in the previous season—a fact which will be found to apply to all the experiments in 1916-17. The amount of *O. cernua*, however, in each plot was very greatly increased. Thus last year plot (A) had only 185 *O. cernua* but this year it had 4,709. The significance of these results in relation to the application of the nitrate will be considered, in conjunction with the results of other experiments, later.

(*b*) *Mustard.* The two plots (C and D) were sown with mustard on October 11th and 20 lb. of sodium nitrate was scattered on the western plot (C) on October 30th, when the young plants were up. The crop grew well but in both plots the "tokra" seemed to be later and less than in the previous season. The crop was cut on February 3rd and the figures were:—

	Weight of mustard	Number of mustard plants	Number of *O. indica*
Manured (C) ..	10½ mds.	3,753	1,402
Unmanured (D) ..	7¼ ,,	4,109	732

These figures show that the amount of *O. indica* in both plots was very much less in 1916-17 than in the previous season. No reason can be given for this. Comparing the two plots with one another in each season it is seen

that the western plot (C) always had the most "tokra" irrespective of whether it had received sodium nitrate or not. *O. cernua* was not present.

(*c*) *Cabbage.* The same two plots (E and F), as in the season 1915-16 were planted out with cabbages. Each plot contained 196 cabbage seedlings and each seedling in the western plot (E) received 1 oz. of sodium nitrate applied in solution in three doses. The "tokras" were counted on 28th February and the figures were :—

		Number of cabbages	Number of *O. indica*
Manured (E)	..	196	592
Unmanured (F)	..	196	642

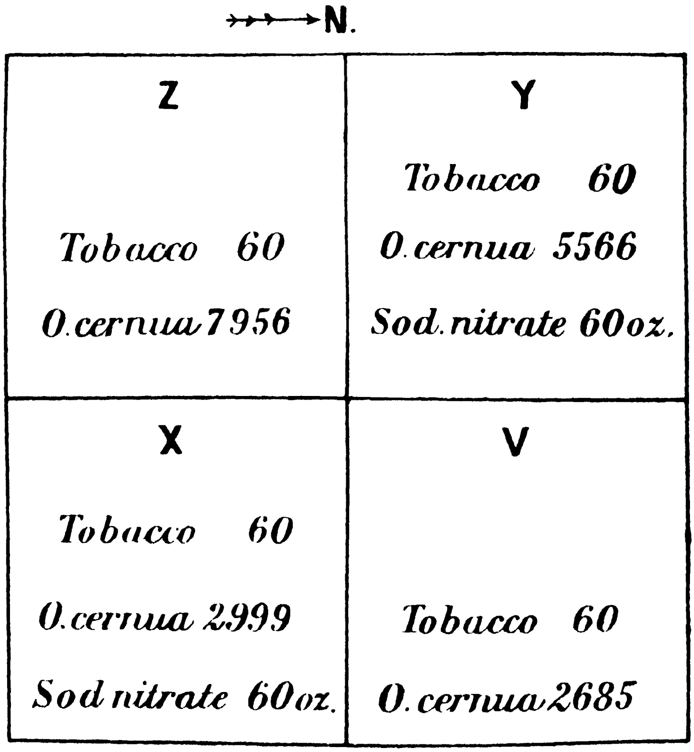
O. cernua was not present at all. These results agree with those of the previous season in the fact that the quantity of "tokra" in the manured plot (E) was substantially the same as in the unmanured plot (F)- although the same plot had received the nitrates in two successive years. The most striking difference is in the actual amount of *O. indica* present in the second season relative to what was present in the first, a comparison showing a reduction from about 3,000 to 600 in both plots. This peculiarity has already been mentioned in the case of the tobacco and mustard at Pusa and appears also in that crop at Birowlie. It is important to notice that the decrease affects equally manured and unmanured plots and is entirely independent of the application of sodium nitrate

Tobacco New Plot. During the season 1915-16, a plot (about one-twentieth acre) of tomatoes in the kitchen garden was noticed to be suffering severely from both *O. cernua* and *O. indica.* This plot was ploughed and harrowed in May 1916 and after cultivation was planted out with tobacco in October. The tobacco was planted in 8 rows of 30 plants in each row, the lines selected being those in which the tomatoes had stood during the previous season, the correct position having been marked before taking up the tomatoes. The plot was then divided into four equal areas (X, Y, Z, V), and sodium nitrate at the rate of 1 oz. per plant was applied in solution to the south-eastern (X) and north-western quarters (Y) of the plot (Text-figure 5, p. 117).

"Tokra" appeared early in December and came up in large numbers until the crop was cut on 1st March. The amounts of "tokra" present were as follows :—

		Number of tobacco plants	Number of *O. cernua*
Manured areas ..	..	60— 60	2,999 (X)— 5,566 (Y)
Unmanured areas	..	60—60	7,956 (Z)—2,685 (V)

The distribution of these numbers of "tokras" is shown on the plan (Text-figure 5), and it is at once clear that the western half of the field contained the larger number of "tokras" irrespective of any application of the nitrate. It is most interesting to observe that *O. indica* did not come up on the tobacco although in the previous season it had been present on the tomatoes in this field in relatively large numbers.

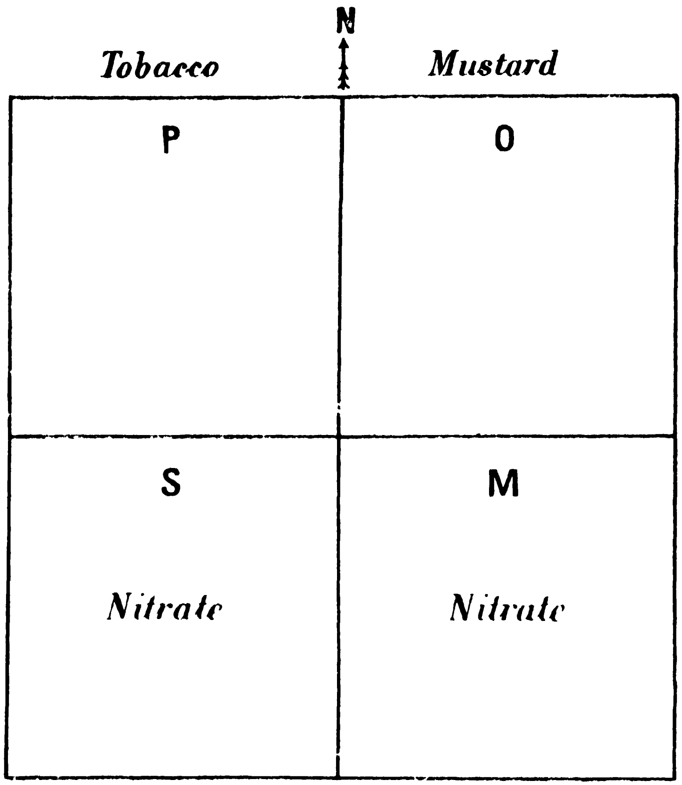


Text-figure 5.

(1) Birowlie Season 1915-16.

During March 1915 a field of tobacco at Birowlie Indigo Factory was very badly infected with "tokra" of which the vast majority were *O. cernua* and a few *O. indica*. A portion of this field was, therefore, selected for experimental work during the cold weather of 1915-16. The experimental area was about one-fifth acre and was divided up into four plots (S, M, O, P); two plots were sown with mustard and two were planted with tobacco at the rate of 288 tobacco plants to each plot. One plot each of tobacco (S) and mustard (M)

received 20 lb. of sodium nitrate spread and mixed with the soil about two weeks before sowing (Text-figure 6).



Text-figure 6.

Mustard. The crop grew well and "tokra" appeared in both plots early in December; it was entirely *O. indica.* There was no appreciable difference in the amount of "tokra" relative to the mustard between the manured and the unmanured plot. As *O. cernua* had been very common in this land in the past season, when it was under tobacco, the predominance of *O. indica* when mustard was grown furnished a good illustration of the differences in their parasitism. In four plants however, *O. cernua* was found attached to the roots of mustard indicating further possibilities in the parasitism of this species. The actual figures were:—

		Number of plants	Number of *O. indica*	Number of *O. cernua*
Manured (M)	..	1,153	2,201	4
Unmanured (O)	..	2,553	3,797	0

The depredations of some stray cattle were responsible for the paucity of mustard in the manured plot.

Tobacco. The tobacco crop grew well at first but "tokra" appeared early in December and continued to come up in ever increasing numbers causing large cracks to appear all round the tobacco plants. Whether from the loss of moisture through these cracks or from the actual parasitic effect of the "tokra," the tobacco had a wilted appearance, this condition was most noticeable in the afternoon. In February the whole field was full of "tokra," a certain amount of *O. indica* being mingled with *O. cernua* (Plate II, fig. 1 Plate III, figs. 5 and 6). On the 20th February the crop had a very poor appearance and was cut. The following figures give the actual amounts of the two species of *Orobanche* in comparison with the tobacco :

		Number of tobacco plants	Number of *O. cernua*	Number of *O. indica*
Manured (S)	..	287	16,574	1,999
Unmanured (P)	..	288	9,976	1,700

These figures are most emphatically against the claim that sodium nitrate may be used as a preventive against "tokra." In comparison with the figures for the mustard plots, those for the tobacco show the extent to which the species which is the chief parasite of one crop can infect the other crop.

(5) Birowlie—Season 1916-17.

The same field was placed under mustard and tobacco as in the previous season (Text-figure 6).

Mustard. Sodium nitrate (20 lb.) was scattered upon the southern mustard plot (M) about two weeks after sowing. The crop grew badly and, as at Pusa, "tokra" was later in appearing and less in amount than in the previous season. The crop was cut on February 18th.

		Weight of mustard		Number of plants of mustard	Number of *O. indica*
		Mds.	Srs.		
Manured (M)	..	3	6	3,445	687
Unmanured (O)	..	2	28	2,816	1,104

There was no *O. cernua* in the mustard. These figures show that in 1916-17 the total amount of *O. indica* in both plots was very much less than in the previous season; this fact has already been noticed in the case of the Pusa experiment. No explanation can be given as to why the season 1916-17 appears to have been less favourable to *O. indica*.

The distribution of the "tokra" in the manured and unmanured plots was the same as in last year; the southern (manured) plot (M) had the smaller amount of "tokra."

Tobacco. Tobacco was planted out in the two plots next to the mustard as in the previous season, the number of plants in each plot being increased in 1916-17 from 288 to 342. The nitrate was applied to the same plot as in the season 1915-16 but was given in solution at the rate of 1 oz. to each plant. The total quantity of nitrate used thus came to about 22 lb.

"Tokra" appeared at the end of November and continued to come up until the crop was cut on 26th February, by which date the tobacco was in a very bad condition. The actual amounts of "tokra" present were as follows :—

	Number of tobacco plants	Number of *O. cernua*	Number of *O. indica*
Manured (S) .	342	17,291	142
Unmanured (P) .	342	14,822	981

In comparison with the previous season the total amount of *O. cernua* shows an increase in both plots, the larger quantity being, as in the previous season, in the manured plot, the increase, however, is proportionately greater in the unmanured plot. The amount of *O. indica* present shows the decrease which has already been mentioned as occurring in all the experiments in the season 1916-17.

III. POT CULTURE, 1916-17.

The fact that the tobacco grown at Pusa in a field which was known to be infected with seed of *O. indica* suffered from "tokra" only very slightly in the first year, and in the second year contained far less *O. indica* than the adjoining plots of mustard and cabbage, in conjunction with the fact that one field of tobacco outside Pusa was found to be practically destroyed by this species, suggested that the morphological species *O. indica* possibly contained two races differing in their parasitic properties.

With a view to testing the parasitism of *O. cernua* and *O. indica* on different hosts, with greater accuracy than was possible within the limits of a field experiment, a series of pot cultures was made at Pusa during the cold weather of 1916-17. Soil for the pots was obtained from land which had been lying fallow for a large number of years, and which was not known to have ever been under a crop liable to the attack of *Orobanche*. There was therefore a strong probability that such soil would not contain any seed of *Orobanche* and moreover a number of the pots, filled with a mixture of leaf-mould and this soil, were sterilized in the steam sterilizer in order to kill any chance seeds

which might be present. As, however, the conditions necessary for the germination of the seed of parasites such as *Orobanche* are known to be delicate, it was not considered advisable to sterilize all the pots. In all 92 pots were used of which 36 were planted with tobacco, 21 with mustard, 16 with turnip (*Brassica campestris* var. *rapa*) and 16 with cabbage. These pots were then infected with seed of *O. cernua* and *O. indica* which had been collected in the season 1915-16. In the case of *O. cernua* the seed used had been collected from three distinct sources—from plants which were parasitic on tobacco, from plants which were parasitic upon tomato and from plants which were parasitic upon brinjal (*Solanum Melongena* Linn.) In the case of *O. indica* the seed used was obtained from four sources, namely, from plants parasitic respectively upon cabbage, mustard, turnip, and tobacco. For convenience in this account the particular kind of seed of *Orobanche* is indicated by the addition of the name of the host plant, from which it was collected, after the specific name; thus seed *O. indica cabbage* means seed of *O. indica* collected from plants parasitic upon cabbage. In this way it was hoped to observe whether the influence of the previous host had any effect upon the parasitism of the seed of either *O. cernua* or *O. indica*. The number of pots sterilized was 16, and 16 pots received each 1 oz. of sodium nitrate when the host plants were well established. These details are apparent in the list of the pots (page 123) and in the plan of the experiment. (Text-figure 7.)

Seed *O. cernua tobacco* was infected upon four pots each of tobacco, mustard, cabbage, and turnip. This was done by scattering a quantity of the seed on the surface of the soil and mixing lightly with a small stick. In the case of tobacco and cabbage the host plant had been planted in the pot some days previously; in the mustard and turnip pots the seed of the parasite was sown mingled with that of the host. Half of the pots had received 1 oz. each of sodium nitrate. After about six weeks (from November 8th to 15th) plants of *O. cernua* appeared in three of the tobacco pots and considerably later (2nd January) also in the fourth pot of tobacco. Those pots which had received nitrate were indistinguishable, except in regard to the development of the host, from the others. No plants of *O. cernua* appeared in the pots of mustard, cabbage, or turnip. Late in January, when the pots had been standing in the open for four months, a few plants of *O. indica* appeared in one pot of cabbage and three pots of turnip. The time at which they appeared, coupled with the fact that they were not of the species of *Orobanche* used in the infection, indicates that their origin is to be attributed to chance infection by air-borne seed after the experiment was started.

Seed *O. cernua brinjal* was infected upon eight pots of tobacco, four of which received 1 oz. each of sodium nitrate. In the first six weeks "tokra" came up in all the non-nitrate pots and in two of the nitrate pots. In the two remaining nitrate pots it did not appear until after the lapse of three months. Seed *O. cernua tomato* infected upon tobacco behaved in much the same manner, but in one pot, which had received sodium nitrate, "tokra" did not appear.

Seed *O. indica cabbage* was infected upon four pots each of tobacco, mustard, cabbage, and turnip: half of the pots had received 1 oz. each of sodium nitrate. No "tokra" at all appeared upon the tobacco: "tokra" (*O. indica*) came up in all the pots of mustard and turnip and in two of the pots of cabbage. It did not appear in the two cabbage pots which had received nitrate, and in the mustard and turnip nitrate pots it was distinctly later in appearing than in the non-nitrate pots. Seed *O. indica mustard* behaved in exactly the same way as the seed *O. indica cabbage* when infected upon tobacco, mustard, cabbage, and turnip. Here, again, "tokra" was much later in appearing in the nitrate pots and in one nitrate pot of cabbage did not come up at all. Seed *O. indica turnip* gave the same result, coming up on mustard, cabbage and turnip but not appearing in the tobacco pots. "Tokra" was again late in the nitrate pots and did not appear at all in the cabbage pots which had nitrate.

It has been mentioned previously in this account that *O. indica* is sometimes found parasitic upon tobacco. Seed of *O. indica* from this source was accordingly used to infect eight pots of mustard and four pots of tobacco. In the eight pots of mustard "tokra" only appeared in two pots and in each of these pots there was only one "tokra" and that a very small and weak specimen of *O. indica*. In all the tobacco pots "tokra" appeared very abundantly; it was appreciably later in those pots which had received nitrate but still each of the four pots had about 50 "tokras." In every case this "tokra" was *O. indica* and was morphologically indistinguishable from the "tokra" which had appeared in the mustard, cabbage, and turnip pots when these were infected with seed of *O. indica* from cabbage, mustard, and turnip hosts. Yet these latter varieties of *O. indica* seed failed to give any "tokras" when infected upon tobacco. It appears therefore that seed of *O. indica* collected from mustard, cabbage, and turnip hosts will infect these hosts and will not infect tobacco, while seed of *O. indica* collected from tobacco host will infect tobacco and will hardly infect mustard at all.

The facts established by these pot cultures therefore appear to be as follows :—

(1) Seed *O. cernua tobacco* is strongly parasitic upon tobacco, does not infect mustard, cabbage, and turnip, and its incidence upon tobacco is not influenced by applications of sodium nitrate.

(2) Seed *O. cernua brinjal* and *O. cernua tomato* is strongly parasitic upon tobacco and is slightly influenced by nitrate.

(3) Seed *O. indica mustard*, *O. indica cabbage*, and *O. indica turnip* do not infect tobacco but come up equally on the other three hosts ; applications of nitrate delay the appearance of the "tokra."

(4) Seed *O. indica tobacco* comes up strongly upon tobacco but very slightly upon mustard ; nitrate has the same effect as upon the other varieties of seed of *O. indica*.

The most interesting point brought out by these results is that the morphological species *O. indica* appears to consist of two races. One race is strongly parasitic upon *Cruciferæ* and does not attack tobacco (*N. tabacum*) and the other race attacks tobacco and does not attack *Cruciferæ*. In the field experiments in 1916-17 it has already been mentioned that a crop of tobacco, grown in a field which in the previous season had been under tomato and which then contained plenty of *O. cernua* and *O. indica*, did not contain a single plant of *O. indica*, although *O. cernua* was abundant. This suggests the possibility of further specialisation in the parasitism of *O. indica*. The details of the pot culture experiment are shown in the following list and in the plan (Text-figure 7).

Number of pot	Host and date of planting	Parasite and date of sowing	Sterilization and nitrate	Date of first appearance of "tokra"	Species of tokra	Total number of "tokras" which came up	REMARKS
1	Tobacco 27th Sept.	*O. cernua tobacco* 3rd Oct.	S	8th Nov.	*O. cernua*	17	S—pot sterilized.
2	do.	do.	..	2nd Jan.	do	13	
3	do.	do.	N	16th Nov.	do	21	N = 1 oz. nitrate given
4	do.	do.	N	do.	do.	29	
5	do.	*O. indica cabbage* 3rd Oct.	S	none	none	none	
6	do.	do.	..	do.	do	do.	
7	do.	do.	N	do.	do.	do.	
8	do.	do.	N	do.	do.	do.	

Number of pot	Host and date of planting	Parasite and date of sowing	Sterilization and nitrate	Date of first appearance of "tokra"	Species of "tokra"	Total number of "tokras" which came up	REMARKS
9	Tobacco 27th Sept	*O. indica mustard* 3rd Oct.	S	none	none	none	S=pot sterilized.
10	do.	do.	..	do.	do.	do.	
11	do.	do.	N	do.	do.	do.	N=1 oz. nitrate given.
12	do.	do.	N	do.	do.	do.	
13	do.	*O. indica turnip* 3rd Oct.	S	do.	do.	do.	
14	do.	do.	..	do.	do.	do.	
15	do.	do.	N	do.	do.	do	
16	do.	do.	N	do.	do.	do.	
17	Mustard 14th Oct.	*O cernua tobacco* 14th Oct.	S	do.	do.	do.	
18	do.	do.	..	do.	do	do.	
19	do.	do.	N	do.	do.	do.	
20	do	do.	N	do.	do.	do.	
21	do.	*O. indica cabbage* 14th Oct.	S	30th Nov.	*O. indica*	20	
22	do.	do.	..	12th Dec.	do.	13	
23	do.	do.	N	6th Jan.	do.	24	
24	do.	do.	N	20th Dec.	do.	43	
25	do.	*O indica mustard* 14th Oct	S	26th Nov.	do	9	
26	do.	do	..	2nd Dec.	do.	51	
27	do.	do.	N	6th Jan.	do.	11	
28	do.	do.	N	19th Dec.	do.	21	
29	do.	*O. indica turnip* 14th Oct.	S	2nd Dec.	do.	10	
30	do.	do.	.	6th Dec.	do	85	
31	do.	do.	N	2nd Jan.	do.	112	
32	do.	do.	N	do.	do.	47	
33	Cabbage 23rd Oct.	*O. cernua tobacco* 23rd Oct.	S	none	none	none	
34	do.	do.	..	do.	do.	do.	One plant of *O. indica*, result of chance infection, appeared on 12th January.
35	do.	do	N	do.	do.	do.	
36	do.	do.	N	do.	do.	do.	
37	do.	*O. indica cabbage* 23rd Oct.	S	6th Dec.	*O. indica*	29	
38	do.	do.	..	9th Dec.	do.	68	
39	do.	do.	N	none	none	none	
40	do.	do.	N	do.	do.	do.	
41	do.	*O. indica mustard* 23rd Oct.	S	6th Dec.	*O. indica*	16	

Number of pot	Host and date of planting	Parasite and date of sowing	Sterilization and nitrate	Date of first appearance of "tokra"	Species of "tokra"	Total number of "tokras" which came up	REMARKS
42	Cabbage 23rd Oct.	*O. indica* mustard 23rd Oct.	..	6th Dec.	*O. indica*	28	
43	do.	do.	N	17th Jan.	do.	19	N=1 oz. nitrate given.
44	do.	do.	N	none	none	none	
45	do.	*O. indica* turnip 23rd Oct.	S	13th Dec.	*O. indica*	49	S=pot sterilized.
46	do.	do.	..	9th Dec.	do.	48	
47	do.	do.	N	none	none	none	
48	do.	do.	N	do.	do	do.	
49	Turnip 23rd Oct.	*O. cernua* tobacco 23rd Oct.	S	do	do.	do	A few plants of *O. indica* appeared in these pots towards end of January—the result of chance infection by air-borne seed.
50	do.	do.	..	do.	do.	do.	
51	do.	do.	N	do.	do.	do.	
52	do.	do.	N	do.	do.	do	
53	do.	*O. indica* cabbage 23rd Oct.	S	6th Dec.	*O. indica*	13	
54	do.	do.	..	19th Dec.	do.	39	
55	do.	do.	N	2nd Jan.	do.	13	
56	do.	do.	N	14th Dec.	do.	56	
57	do.	*O. indica* mustard 23rd Oct.	S	6th Dec.	do.	28	
58	do.	do.	..	6th Dec.	do.	26	
59	do.	do.	N	19th Jan.	do.	24	
60	do.	do.	N	do.	do.	19	
61	do.	*O. indica* turnip 23rd Oct.	S	14th Dec.	do.	29	
62	do.	do.	..	6th Dec.	do.	16	
63	do.	do.	N	30th Jan.	do.	20	
64	do.	do.	N	10th Jan.	do.	65	
65	Tobacco 27th Sept.	*O. cernua* brinjal 3rd Oct.	S	20th Nov.	*O. cernua*	34	
66	do.	do.	..	15th Nov.	do.	72	
67	do.	do.	..	do.	do.	78	
68	do.	do.	..	20th Nov.	do.	42	
69	do.	do.	N	8th Nov.	do.	29	
70	do.	do.	N	do.	do.	61	
71	do.	do.	N	10th Jan.	do.	41	
72	do.	do.	N	do.	do.	42	
73	do.	*O. cernua* tomato 3rd Oct.	S	1st Dec.	do.	87	
74	do.	do.	..	20th Nov.	do.	53	
75	do.	do.	..	do.	do.	32	

Number of pot	Host and date of planting	Parasite and date of sowing	Sterilization and nitrate	Date of first appearance of "tokra"	Species of "tokra"	Total number of "tokras" which came up	REMARKS
76	Tobacco 27th Sept	*O. cernua* tomato 3rd Oct	..	6th Dec.	*O. cernua*	46	
77	do	do	N	none	none	none	N=1 oz. nitrate given.
78	do.	do.	N	19th Jan.	*O. cernua*	58	
79	do.	do.	N	20th Dec.	do.	36	
80	do.	do.	N	do.	do.	46	
81	Mustard 14th Oct	*O indica* tobacco 14th Oct	S	none	none	none	S=pot sterilized.
82	do	do	..	do.	do.	do.	
83	do	do	.	do.	do.	do.	
84	do	do.	.	11th Dec.	*O. indica*	1	Probably result of chance infection by air-borne seed.
85	do.	do	N	none	none	none	
86	do	do.	N	do.	do.	do.	
87	do	do.	N	do.	do.	do.	
88	do	do.	N	12th Jan.	*O. indica*	1	Ditto
89	Tobacco 3rd Oct.	*O indica* tobacco 3rd Oct	S	12th Dec.	do.	60	(see Plate 1, fig 2.)
90	do	do	..	do	do	46	One plant of *O cernua*—the result of air-borne infection—the remainder all *O. indica*.
91	do	do	N	2nd Jan.	do.	52	
92	do	do.	N	10th Jan.	do.	50	

IV. CONCLUSIONS.

Considering the question whether applications of sodium nitrate can be advocated as a preventive for "tokras" the results of the experiments described in this paper cannot be said to support that view.

In the case of cabbage the field experiments at Pusa did not show any diminution in the amount of *O. indica* in the plot which had the nitrate, relative to that which had not received any nitrate. With mustard, both at Pusa and at Birowlie, it was found that the plot which had the larger number of "tokras" (*O. indica*) in one season was that which had the larger number in the previous season and that the application of sodium nitrate did not alter these proportions. It is of course not contended that the application of sodium nitrate is without benefit to the mustard but simply that it is not a specific against the "tokra" which is parasitic upon mustard and cabbage.

Parasite / **HOST.**

Host	O.CERNUA OF TOBACCO			
TOBACCO	1 S C_{17}	2 C_{13}	3 N C_{21}	4 N C_{29}
MUSTARD	17 S	18	19 N	20 N
CABBAGE	33 S	34	35 N	36 N
TURNIP	49 S	50	51 N	52 N

Host	O.INDICA OF CABBAGE			
TOBACCO	5 S	6	7 N	8 N
MUSTARD	21 S I_{20}	22 I_{13}	23 N I_{24}	24 N I_{43}
CABBAGE	37 S I_{29}	38 I_{68}	39 N	40 N
TURNIP	53 S I_{13}	54 I_{39}	55 N I_{13}	56 N I_{56}

Host	O.INDICA OF MUSTARD.			
TOBACCO	9 S	10	11 N	12 N
MUSTARD	25 S I_{9}	26 I_{51}	27 N I_{11}	28 N I_{21}
CABBAGE	41 S I_{16}	42 I_{28}	43 N I_{19}	44 N
TURNIP	57 S I_{28}	58 I_{26}	59 N I_{24}	60 N I_{19}

Host	O.INDICA OF TURNIP			
TOBACCO	13 S	14	15 N	16 N
MUSTARD	29 S I_{10}	30 I_{85}	31 N I_{112}	32 N I_{47}
CABBAGE	45 S I_{49}	46 I_{48}	47 N	48 N
TURNIP	61 S I_{29}	62 I_{16}	63 N I_{20}	64 N I_{65}

Host	O CERNUA OF BRINJAL.							
TOBACCO	65 C_{34}	66 C_{72}	67 C_{78}	68 C_{42}	69 N C_{29}	70 N C_{61}	71 N C_{41}	72 N C_{42}

Host	O CERNUA OF TOMATO.							
TOBACCO	73 C_{87}	74 C_{53}	75 C_{32}	76 C_{46}	77 N	78 N C_{58}	79 N C_{36}	80 N C_{45}

Host	O INDICA OF TOBACCO.							
TOBACCO	89 I_{60}	90 I_{46}	91 N I_{52}	92 N I_{50}				
MUSTARD	81	82	83	84 I_{1}	85 N	86 N	87 N	88 N I_{1}

S = sterilised
N = 1oz nitrate given
C = O cernua
I = O. indica
The large numeral is the number of the pot and the small numeral gives the total number of tokras which came up in that pot.

Text-figure 7

In the case of the tobacco the results of the field experiments were not so obvious. At Birowlie in two successive seasons the larger quantity of *O. cernua* appeared in one particular plot, although this plot received a heavy application of sodium nitrate in each season. This suggested that the incidence of "tokra" in a field was dependent upon factors, other than the application of nitrate, such as the amount of "tokra" seed present and the resulting degree of infection of the soil. The results of the experiments in the "new plot" at Pusa in 1916-17 confirm this view. A reference to Text-figure 5 will show that in this plot the *O. cernua* occurred chiefly in the western half of the field and was not materially influenced by the nitrate. The two original tobacco plots, A and B, gave results which superficially did not agree with this. In these plots the amount of *O. cernua* was less in the areas which had received the nitrate. This was most marked in the case of the plot B which had not had any manure in the two previous seasons, and received an application of nitrate upon half its area for the first time in the season 1916-17. In this plot the unmanured area contained about 30 plants of *O. cernua* to every tobacco plant and the manured area contained about 15 plants of *O. cernua* to each tobacco plant. But a proportion of 15 "tokras" to each tobacco plant in the manured area appears, in the writer's opinion, too large to justify the claim of any curative properties against "tokra" for nitrate of soda. Moreover it must be pointed out that in the two plots A and B in the season 1916-17, the amounts of "tokra" in the two unmanured areas differed from one another nearly as much as when the comparison was made between one of the areas which had received nitrate and one which had not received any (*see* page 115). If applications of sodium nitrate were likely to prove a preventive against "tokra" a result would surely have appeared in the pot cultures, where the application of 1 oz. to each pot was at the rate of several tons to the acre. In this case, however, *O. cernua* on tobacco was almost quite uninfluenced by the nitrate and the most favourable result obtained with other crops was a delay in the appearance of the "tokra."

Chili saltpetre therefore can hardly be advocated as a cure for "tokra." In a valuable crop, such as tobacco, and in a district where labour is as cheap as it is in Bihar, much may be done to keep these pests down by hand-weeding, the "tokras" being uprooted before they have formed mature seed which could infect the soil for the succeeding crop. With a crop such as mustard it might be possible to cultivate early varieties, which ripen before the "tokra" has matured its seed, and by ploughing immediately after harvesting to bury the

"tokra" before its seed has ripened. In this connection it may be mentioned that the practice of taking a second cut from the tobacco is a bad one; the longer the tobacco is kept in the soil the more "tokras" come up and the more seed is matured to infect the soil for the next crop.[1]

It is evident that the parasitism of *O. indica* is much more complicated than that of *O. cernua*. *O. cernua* is practically restricted to solanaceous crops; in all the thousands of "tokra" counted only four specimens of *O. cernua* were found upon mustard. *O. indica* has, however, a much wider range of hosts as is evident from a glance at the list (page 130). Field observations suggested, and pot culture experiments have shown, that in *O. indica* there are at least two races, one of which is parasitic upon tobacco and does not attack mustard, while the other is parasitic upon mustard, turnip, and cabbage and does not attack tobacco. It has been proved by other investigators[2] that the seed of some phanerogamic parasites (e.g. *Orobanche, Tozzia*) will not germinate except in the presence of the appropriate host. If the conditions for the germination of the seed of such parasites are so delicately adjusted to their environment it is not surprising to find that in a morphological species such as *O. indica*, differences in parasitic quality may exist without accompanying morphological distinctions.

In this connection the scarcity of *O. indica* in the second season indicates that the slight climatic differences between two successive cold seasons may have a powerful influence in determining the amount of this parasite, and Beck von Mannagetta considers that some species, notably *O. cernua*, have shown marked morphological variations in their spread to regions of different climates.

Plants such as *Orobanche* have always attracted a good deal of attention from botanists. One of the earliest works on this genus appears to be that of Vaucher[3], who gives a list of parasitic species and their hosts and made some observations on the germination of *O. ramosa* upon *Cannabis sativa*. This was probably one of the first attempts to grow *Orobanche* in cultures. The biology and anatomy of the genus was very extensively studied by Koch[4], the later monograph of Beck von Mannagetta[5] being rather from a systematic

[1] Howard, A. and G. L. C., "Tobacco cultivation in Bihar." *Agri. Res. Institute, Pusa, Bull.*, No. 50, 1915.

[2] Heinricher, E., *Die Aufzucht und Kultur der Parasitischen Samenpflanzen.* Jena, 1910.

[3] Vaucher, J. P., *Monographie des Orobanches*, Paris, 1827.

[4] Koch, L., *Die Entwicklungsgeschichte der Orobanchen,* Heidelberg, 1887.

[5] Mannagetta, Beck von., *loc cit*, page 108.

standpoint, and received a good deal of attention from Chatin.[1] The work of Fraysse[2] deals with the biology of some phanerogamic parasites, but species of *Orobanche* were not among the number investigated.

Throughout this paper the names of *O. indica* Ham. and *O. cernua* Lœffl. have been used in the sense in which they are used by Hooker. Beck von Mannagetta states that *O. indica* Ham. is synonymous with *O. ægyptiaca* Pers. and gives this species and the nearly related *O. Muteli* Schltz. as being parasitic upon species of *Brassica*, and *O. Muteli* Schltz. and *O. ramosa* L., another related species of the section *Trionychon*, together with *O. cernua* Lœffl. are said to be parasitic upon *Nicotiana tabacum*. It appears therefore that Beck von Mannagetta's observations of the parasitism of *Orobanche* on *Brassica* and *Nicotiana* agree with the facts recorded by Hooker and described in this paper. In a more recent communication[3] the species of *Orobanche* which are parasitic upon tobacco are given as follows :—

O. ramosa L.
O. Muteli Schltz.
O. cernua Lœffl. and *O. cumana* Wallr., a sub species *of O. cernua*.
O. ludoviciana Nutt.

The first two species occur also on hemp, tomato, and *Brassica* and the last species is restricted to North America.

Koch states that heavy applications of manure lessen the incidence of *O. ramosa* upon tobacco for a time but that ultimately the crop becomes diseased and succeeding crops show on the whole a more severe infection. More recently Peters and Schwartz[4] conducted experiments with a variety of chemical substances (copper sulphate, sodium chloride, etc.) without obtaining results which enabled them to recommend applications of these substances against *Orobanche* in tobacco.

[1] Chatin, A., *Anatomie comparee des vegetaux plantes parasites*, Paris, 1892.

[2] Fraysse, A. *Contribution a la biologie des plantes Phanerogames parasites*, Montpellier, 1906.

[3] Peters, L. and Schwartz, M., "Krankheiten und Beschädigungen des Tabaks" *Mitt. Kais. Biol. Anstalt f. Land u. Forstwirtschaft* Heft 13, Berlin, 1912.

[4] Peters and Schwartz, *loc cit.*

List of Host Plants of Genus Orobanche *in Pusa.*

Serial No.	Name of crop	Date of first appearance of "tokra"	Species of "tokra"	Remarks
1	*Brassica campestris* var. *rapa*	30th November	*Orobanche indica* Ham.	The crop was full of this.
2	*Brassica campestris* var. *glauca*	30th November	*Orobanche indica* Ham	The crop was full of this.
	Brassica campestris var. *glauca*	25th January	*Orobanche cernua* Lœffl.	Only four specimens of this were found in Birowlie mustard plot; previously this plot was full of *O. cernua* on roots of tobacco.
3	*Brassica campestris* var. *cauliflora*	3rd January	*Orobanche indica* Ham.	Very little.
4	*Brassica oleracea*	3rd January	*Orobanche indica* Ham.	Crop has been found full of this.
5	*Iberis* sp. (Candy tuft)	18th February	*Orobanche indica* Ham.	
6	*Solanum Melongena*	11th December	*Orobanche cernua* Lœffl.	Only this species has been observed in this host.
7	*Nicotiana tabacum*	7th January	*Orobanche cernua* Lœffl.	Does great damage to this crop.
	Nicotiana tabacum	7th January	*Orobanche indica* Ham.	
8	*Lycopersicum esculentum*	3rd January	*Orobanche cernua* Lœffl.	Good deal of this has been observed.
	Lycopersicum esculentum	3rd January	*Orobanche indica* Ham.	Amount of *O. cernua* is more than *O indica* on this crop.
9	*Petunia*	7th March	*Orobanche cernua* Lœffl.	
	Petunia	15th March	*Orobanche indica* Ham	Very little *O. indica* is found on this host.
10	*Launea pinnatifida*	18th February	*Orobanche indica* Ham.	Only two small specimens.
11	*Bellis* sp. (Daisy)	15th March	*Orobanche indica* Ham.	
12	*Nasturtium*	7th March	*Orobanche indica* Ham.	
13	*Verbena*	7th March	*Orobanche indica* Ham.	
14	*Coleus*	7th March	*Orobanche indica* Ham.	
15	*Cynodon dactylon*	20th February	*Orobanche indica* Ham.	Scarce.

LIST OF ILLUSTRATIONS.

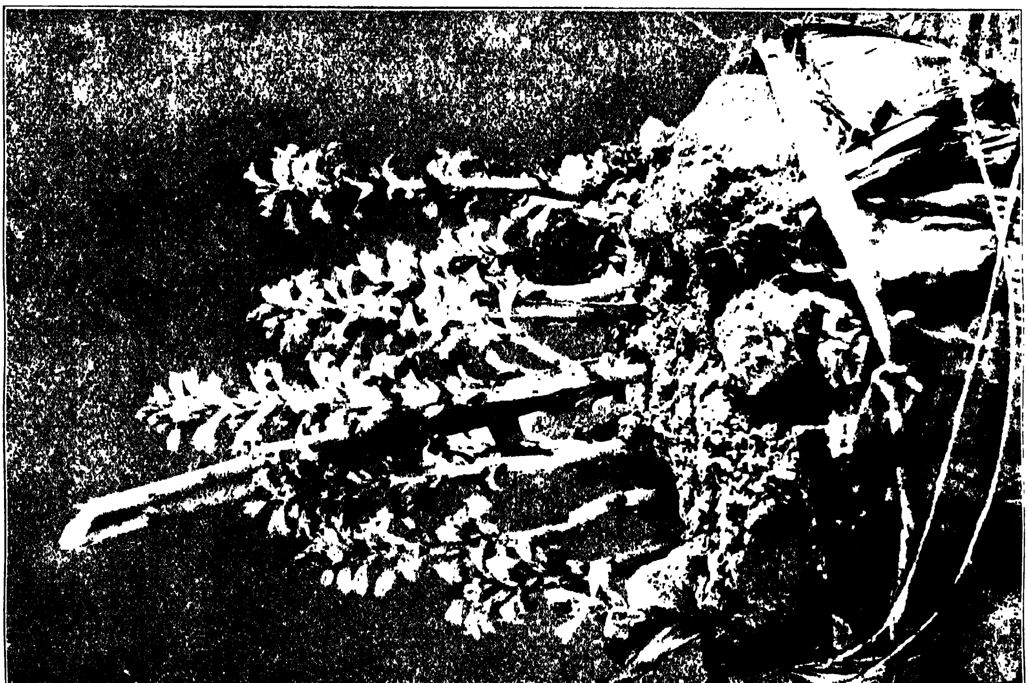


Fig. 1. *Orobanche indica* on mustard

Fig. 2. *Orobanche indica* on tobacco

Fig 3. *Orobanche cernua* on tobacco

Fig. 4. Tobacco field at Birowlie, *Orobanche cernua* and *Orobanche indica*

Fig. 5. Tobacco field at Birowlie; *Orobanche cernua* and *Orobanche indica* in plot which had received sodium nitrate—Season 1915-16.

Fig. 6. "Tokra" at Birowlie in tobacco plot which had not received any nitrate—Season 1915-16.

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May 1918. BOTANICAL SERIES. VOL. IX, No. 4

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STUDIES IN INDIAN SUGARCANES, No 3

THE CLASSIFICATION OF INDIAN CANES WITH SPECIAL REFERENCE TO THE SARETHA AND SUNNABILE GROUPS

BY

C. A. BARBER, Sc.D. (Cantab.)

Government Sugarcane Expert, Madras

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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STUDIES IN INDIAN SUGARCANES, No. 3

THE CLASSIFICATION OF INDIAN CANES, WITH SPECIAL REFERENCE TO THE SARETHA AND SUNNABILE GROUPS.

BY

C. A. BARBER, Sc.D. (Cantab.),

Government Sugarcane Expert, Madras.

[Received for publication on the 25th June, 1917.]

I. INTRODUCTION.

ONE of the first pieces of work undertaken on founding the Cane-breeding Station at Coimbatore was to make as large a collection as possible of the cane varieties growing in different parts of India. This was done, primarily, with the object of obtaining material for the study of these canes when grown together, at the same time and under similar conditions. It was also desired to gain some idea as to the kinds of cane grown in different tracts, so as the more readily to obtain improved varieties suited to them. It was, lastly, hoped that seedlings might be obtained from these canes, of which some might prove useful in replacing their parents. It was known that many of them did not flower in North India and that, in those that did, the anthers were closed and the pollen inside was ill-formed and immature. It was hoped that the change to South Indian conditions might induce some of them to flower, and that the sexual organs might recover tone so as to become better formed and thus more fertile.

A very sharp distinction soon obtruded itself between two classes of cane varieties thus collected. There was a large series of thick, juicy canes, generally excellent in appearance. These were commonly grown on a crop scale in the more tropical parts of India but, in the northern parts, they were usually grown in small plots under high cultivation, near large towns, in which they were used for eating as a fruit. In contrast with this first class there was another, of thin, hardy canes, grown under field conditions all over India, but

especially in the north, which showed themselves capable of growing in the open with comparatively little attention. These were unfitted for chewing and were universally crushed in mills and made into *jaggery* or *gur*.

The number of thick canes accumulated at Coimbatore soon became very large, and there was no evidence of our having exhausted the varieties grown in different tracts. It was noted that they were often only known by the name of the place from which they had been received, with the addition of some such word as "*Paunda*," and a number of them were obviously the same cane hailing from different places. The names frequently suggested that they were introduced or foreign canes and not indigenous in the country. It was found to be difficult to grow them on the untreated land of the Cane-breeding Station and many of those which survived were abnormal in their growth. It was thus seen that any attempts at their classification, which was at first projected, would be extraordinarily difficult, and that it would be idle to commence this, until further details were obtainable as to their migrations and original sources. When a good stock was obtained for seedling work, their further collection was therefore discontinued, or at any rate took a secondary place.

The other class, of thin, *gur*-making varieties, proved, however, to be much more interesting. There was no trace of their having been introduced into India, and there was no country with which I was acquainted from which they could have come. The only exotic varieties of this class, which had been received from abroad, were the *Yuba* cane from Natal, which readily falls into line in the great Pansahi group, and two Java varieties which I have as yet been unable to place in any special Indian class, but which have been imperfectly examined. These thin canes were therefore considered to be indigenous in India, as contrasted with the introduced varieties, and soon showed among themselves several well defined classes which were easily separable. Each year, in planting out the increasing series of thin canes, care was taken to put together all those which showed systematic relationship, so that the plots themselves might indicate the classification. Many of them were, indeed, so similar to one another that the conclusion forced itself on one's mind that, here too, the same canes had been collected under different names from different localities, and that such slight differences as were observable might in all probability be ascribed to the varying conditions of culture and climate under which they had long been grown. The following groups were readily formed, Mungo, Nargori, Pansahi, and Katha, while there were indications of others, such as the transitional Bodi group and the small Khelia section.

But a number of forms were not so easily arranged, and the "unclassified list" steadily increased, without any light being obtained as to their relationships to the groups already collected and isolated. It almost seemed as if there were a large number of isolated forms growing in all parts of the country without any visible genetic connection. Some, such as *Barahi* from the Central Provinces, were as small as the thin and meagre varieties of the Punjab, while others, such as *Naanal* in Madras and *Mojorah* in Assam, were with some difficulty separated from the more juicy canes such as *Puri* of Bihar and *Bonta* of Madras, which appeared to have been introduced at some time, but, after long growth in the country, had apparently decreased in size and vigour. In fact, the rigid separation of exotic from indigenous canes has sometimes been far from easy, and many changes in the unclassified list have been made in consequence. Until a more detailed examination can be made, a certain number of forms will be under doubt, as it does not at first sight seem possible to decide whether such varieties as *Magh* in Assam and *Vendamukhi* in Bengal are in reality introduced or country canes. But the characters of the thick and thin canes, such as their mode of growth and tillering, their size and the relative hardness of their rind, the amount of fibre and juice and their resistance to disease, make the separation of the two classes in general easy enough, and this is emphasized by the character of such seedlings as have been raised from them, in that the parental differences are often exaggerated in the seedlings.

Two varieties placed among the unclassified indigenous Indian canes, still being grown occasionally in the midst of the thick canes of South India, received special attention, because they were more familiar, and we had raised seedlings from them. They were seen to differ markedly in two respects. *Ganda Cheni* from Mysore had bending or nodding leaf ends and well developed circlets of hairs at the nodes, while *Naanal* from Tanjore had more or less erect-tipped leaves and was practically devoid of the circlets of hairs at the nodes. In another place, habit, as here exemplified by the character of the leaf ends, has been regarded as important in classification, whereas it has been suggested that the presence of the circlet of hairs is a primitive character of fundamental importance. These differences, therefore, seemed to indicate that these two canes, like one another in many respects, might belong to entirely different groups. But there was no time available for classification studies until the seedling work had been placed on a firm foundation. The two varieties were obviously to be regarded as indigenous canes, when compared with the thick ones of South India, but their systematic position remained a mystery.

It was first possible during the harvesting season of 1916 to devote some attention to this side of the subject, and a series of more or less hurried comparisons were made between these two canes and the other indigenous varieties collected. Furthermore, it was only then that, by their growth and vigour, the North Indian canes showed that they were thoroughly acclimatized to their new surroundings. The two characters mentioned above, leaf tips and circlets of hairs, inevitably suggested a comparison with the two aboriginal types, *Katha* and *Dhaulu of Gurdaspur* in the Punjab, for these two varieties had been shown to differ in just these two respects.[1] A further study revealed the fact that it was possible to collect many of the unclassified varieties under two heads corresponding with *Ganda Cheni* and *Naanal*, in these and other respects. A preliminary note was sent to the *Agricultural Journal of India*,[2] and a detailed study of the members of the two series was commenced, as far as time was available, during March-April 1916. It was found that varieties of these two groups had been collected from Madras, Mysore, Bombay, the Central Provinces, Bihar, Assam, Bengal, and the United Provinces, besides those already described from the Punjab, with the not surprising tendency constantly to become thicker and more like tropical canes as we proceed eastwards to Assam and southwards towards Madras.

As *Katha* and *Dhaulu* represent the thinnest and most meagre members of these two series, and are only known in the Punjab, new names have been sought for the two classes. And, in selecting these, I have been chiefly guided by the extent to which the varieties are generally known in the Provinces. *Saretha* and *Sunnabile* have, at one time or another, been distributed and tested in almost every Province in India. *Saretha* is a characteristic and valuable cane in the Meerut District and *Sunnabile* is a Bombay cane. They are canes of medium thickness and display the characters of their respective groups sufficiently well. The fact that the name "Sunnabile" appears to be of comparatively rare occurrence in Bombay districts has not been allowed to stand in the way of its selection, because the cane is well known as an introduction on the Government Farms of Madras, the Central Provinces, the United Provinces and the Punjab, and doubtless elsewhere.

[1] Barber, C. A., Studies in Indian Sugarcanes, No. 1, Punjab Canes. *Mem. Dep. Agr. Ind., Bot. Ser.*, Vol VII, No 1, May 1915. This Memoir will in future be referred to as Mem. 1. A second paper by the same author. Studies in Indian Sugarcanes, No. 2, Sugarcane Seedlings, etc., *Mem. Dep. Agr. Ind., Bot. Ser.*, Vol. VIII, No 3, July 1916, will be referred to as Mem. 2.

[2] Barber, C. A., The Classification of Indigenous Indian Canes. *The Agricultural Journal of India*, Vol. XI, Part IV, p. 371

The following are the varieties thus far grown at Coimbatore and, after examination, placed in these two groups. For more exact details as to locality and synonymy, Section V may be referred to (pp. 34 and 35).

Saretha Group: Punjab, *Katha*, *Lalri*, *Kansar*, *Mesangan*; United Provinces, *Raksi*, *Ramui*, *Chin*, *Chunnee*, *Baraukha*, *Burra Chunnee*, *Saretha* (brown), *Saretha* (green); Bihar, *Chynia*, *Jaganathia*; Bengal, *Khari*; Bombay, *Kalkya*; Mysore, *Ganda Cheni*; Madras, *Hullu Kabbu*.

Sunnabile Group: Punjab, *Dhaulu*, *Teru*, *Ekar*; United Provinces, *Rakhra*, *Kaghze*; Assam, *Putli Khajee*, *Mojorah*; Central Provinces, *Dhor*; Bombay, *Bansi*, *Sunnabile*, *Khadya*; Mysore, *Hotte Cheni*; Madras, *Naanal*.

In the description of the prototypes of these two groups, *Katha* and *Dhaulu*, it was noted that some of the differences were equally remarkable for their minute character and their apparent constancy. The same has held in the present study. We have not received much help from characters usually employed in botanical systematic work, such as differences in the floral organs and size of organs and plants, but have been dependent on a series of minute local differences, a well known occurrence in the separation of closely allied cultivated varieties. Thus, in all of the Saretha group, there is a minute black incrustation on the rind, as if it had been attacked by a small mite, whereas this is entirely absent in the Sunnabile group. The density of bloom is greater in the Saretha group but the blackening of this bloom by fungus is much sharper and more circumscribed in the Sunnabile group. Minute characters of this kind thus become of prime importance in classification, just as the greater liability of certain classes of canes to different fungus attacks. Thickness of stem and size and vigour of plant seem to be of no value, in that, in each series, we pass from the smallest and thinnest canes in India to great growths with difficulty distinguished from luxuriant tropical canes. And the very insistence of these insignificant characters, in canes so widely differing in external appearance and extending through such wide stretches of country under such different climatic and cultural conditions, does but add to their importance. Other characters than those mentioned above, which have helped to distinguish the two groups are :—The presence or absence of the groove, the brown coloration on the stem, the arrangement and frequency of the corky lines (ivory markings) on the stem, the presence of the scar band and scar line, the bursting of buds, whether apical or dorsal, the character of hairs on the bud, the colour of the edges of the young leaf-sheath, the presence or absence of spiny hairs on the back of the leaf-sheath, the venation of the leaf-sheath, the extent to which the leaf-sheath clasps the stem at its base, the character of the ligular

hairs, the width and shape of the leaves, the relations between their length and width (leaf module), the erectness of the leaf tips, the length and thickness of the joints and the cane module, the number of joints in the cane, the obliqueness of the first formed shoots, the nature of the underground branching, freedom of flowering and seed formation, the roughness of the surface of the leaves and the nature of the serrature on their edges, and so forth. Some sixty to seventy such characters are dealt with below, many of them of prime importance, while in others the groups hang together generally but exceptions occur.

The two new classes of indigenous canes thus differ markedly from those already recognized. Thus far, we have depended in our grouping on obvious resemblances by which, at a glance, varieties could be placed together, as if the same cane had been grown for long periods in different tracts. The members of the new classes often show no such obvious likeness, and it has required a great deal of detailed study of many minute characters according to a prepared scheme, before we could decide on definitely placing each member in its proper class. Certain varieties, such as the great, grass-green *Putli Khajee*, are noted for the number of minor deviations, and there are other canes, such as *Shakarchynia* and *Barahi*, showing obvious connections, but with sufficiently important differences to prevent at present their inclusion in either class. Such cases may prove of special interest later, as showing transitions between the classes now dealt with and others as yet undetected, or they may be simply blind variations with no further relationship.

We have thus before us an interesting mass of information as to the systematic value of the numerous characters which have formed the basis of our cane descriptions, one of the desiderata set before us at the commencement of our study.[1] In the classification of the two groups, we see that it is more to the concurrence of a number of apparently unimportant resemblances that we must look for the proper grouping of our cane varieties, than to characters of real morphological significance, so commonly and successfully employed in the classification of plants. There is little doubt, moreover, that, to the characters detailed in this paper, may be added fundamental differences in the quality of the juice, fibre content, milling properties, requirements of soil and water, and general hardiness and liability to disease, and there are indications that such is the case. The members of the Saretha class are apparently hardier and less dependent on water than the Sunnabile varieties, and also have less juice but with more saccharine content. But a lack of first-hand

[1] Barber, C. A., Some Difficulties in the Improvement of Indian Sugarcanes. *Annals of Applied Biology*, vol 1, nos. 3 and 4, Jan. 1915, p. 219, "Problem 6."

knowledge of the canes in their natural conditions and the opinions of local cultivators regarding them, prevents us from analysing these characters at present. Enough has been said to show that, to the already well recognized groups of Indian canes typified by *Mungo*, *Pansahi*, *Nargori*, two more classes, less obviously marked to the casual observer but none the less genuine, must.be added. In these groups the usual separation of the canes into *Ukh* and *Ganna* breaks down, and, indeed, there are some indications of a further gradation between the latter and the *Paunda* class. If this turn out to be the case, we shall perhaps be able ultimately to throw light on the hitherto insuperable gulf between the indigenous Indian and exotic tropical canes, a gulf which has led to the idea that we have in them two groups of cultivated plants closely related and yielding the same commercial substance, but arising from different wild parents. I know, at present, of no single, fundamental difference between these two groups, and regard it as quite possible that, in India itself, we may find the transition from one to the other. Historically, at any rate, the cultivated canes of the tropics have been traced to Northern India, and we may at present rest at that.

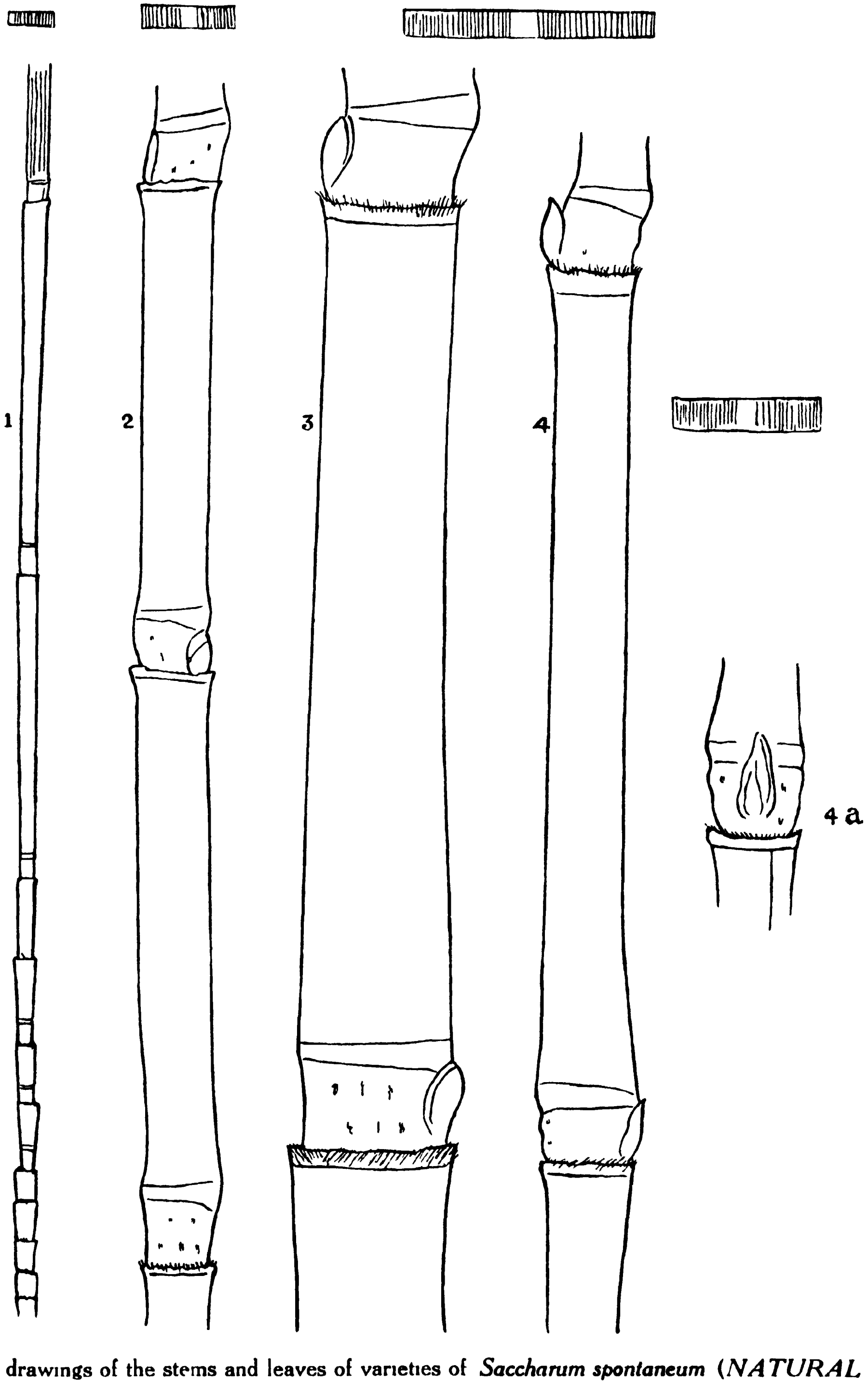
But there is another aspect of this study to which attention may be drawn. Our classification is not merely an empirical statement of unconnected differences, a sort of analytical key for the separation of varieties, but presents the data for a reasoned statement regarding the lines of evolution among a section of cultivated canes. We also claim to have made distinct advances along the difficult path of tracing the origin of cultivated canes from their wild ancestor.

There are, as already stated, in each class, a series of cane varieties, passing more or less imperceptibly from what are confessedly the thinnest and most primitive canes in the world to thick, well-developed forms showing distinct resemblances to tropical sugarcanes. By the careful study of the variation between these extremes, we are placed in a better position for tracing the evolution of the latter from primitive ancestors. And, what is more significant, we have established a series of connecting links between cultivated canes and wild Saccharums now growing in India.

Our study of *Saccharum spontaneum* is still incomplete, as the full method proposed is to examine and compare a large series of seedlings of this species, in order to establish the limits of variation in the vegetative organs. But a constant collection of specimens, while on tour in different parts of India, has demonstrated the fact that there are some very distinct varieties of this species, more or less confined to definite geographical regions. There is the common wire-leafed weed, usually known as *kans* or *kahi* grass, met with all over India,

but more abundant in the dry tracts. As we proceed to the more humid regions, Bengal, Assam, Burma, this form, although present, shows transitions to wider-leafed and thicker-stemmed forms, till we get canes with leaves nearly a couple of inches wide and stems as thick as *Ganna* canes. There is, moreover, a water form which is typically present in the ponds near Dacca, in the old alluvium of the Madhapur forest, with tender green nodding leaves and thickish stems rooting abundantly at the nodes, which in many respects is much more like a cultivated cane than the dry land form (Plates I and II). I learn from an Assistant Farm Manager at Dacca that this form is termed *kashi* in the Hooghly District, where it is common on the alluvial banks of streams. He says that it is given to children to chew and that his grandfather states that in former times it was crushed for making *gur*. Whether there be any truth in this or not, it is interesting to note that, among the seedlings obtained from it at the Cane-breeding Station, some had juice with over 8 per cent. of sucrose, which is higher than any yet obtained in our analysis of wild Saccharums. This form suggests a starting point for primitive cultivated canes. Throughout Burma we meet with a series of forms which appear to connect these two latter (the thick land form and the water form), sometimes in ponds, but more usually on the alluvial banks of the Irrawady, varying considerably in the thickness of the stem and width of the leaves. All of these have the typical inflorescence of *Saccharum spontaneum* and must therefore be included in that botanical species. They have been introduced into the Cane-breeding Station at Coimbatore and show themselves perfectly able to cross with the cultivated canes there, whether thick or thin. We have raised seedlings by selfing each of them, but at present there has been no opportunity of examining these in a detailed manner. We thus see in *Saccharum spontaneum* a development in the size of the vegetative organs, as we pass from the dry to the humid tracts in India, similar to that met with in the Saretha and Sunnabile series of sugarcanes. Attention has been drawn to the obvious resemblance between the *kahi* grass and *Katha* in the Punjab, where the local ryots are accustomed to point out *kahi* as the ancestor of *Katha*, their commonest cane.[1] In the detailed list of characters showing differences between the Sunnabile and Saretha groups, we shall find a number mentioned in which the latter group approaches *Saccharum spontaneum*. Such are the black incrustation on the stem, the venation and transverse bars on the leaf-sheath, the prominence of the midrib, the circlet of hairs on the nodes, the serrature of the leaf and the extent of roughness on the surface at the leaf tip, the red brown colour of many

[1] Mem. I. p. 2.



Outline drawings of the stems and leaves of varieties of *Saccharum spontaneum* (*NATURAL SIZE*)

1. *Kahi* grass, a very thin form from Kamrup, Assam.
2. *Kurivi Naanal* a rather thick-stemmed Madras form.
3. *Gehra Bon*, a tall, thick-stemmed, hedge plant with broad leaves, Kamrup, Assam.

Saccharum spontaneum, a water form, collected in Dacca ponds and grown in a damp place in the Cane-breeding Station at Coimbatore

Seedlings of *Saccharum spontaneum* On the right, two rows of seedlings of the Dacca form ; on the left

seedlings, the mode of branching, etc., and we have utilized these resemblances to *Saccharum spontaneum* as strengthening our conviction that the Saretha series is the more primitive. But there is also some reason for supposing that the more highly developed Sunnabile varieties are also traceable to *Saccharum spontaneum.* Among the characters in which the Sunnabile and Saretha groups differ are the bending of the leaf tip, the erectness of the young (germinating) shoots, the colour of the stem, the ligule and its setæ, spines on the backs of the leaf sheaths, scar band and scar line, and so on. Now a more or less imperfect study of the seedlings of *Saccharum spontaneum* raised at Coimbatore has also shown these very differences among themselves; there are white and brown stemmed forms, the ligules vary and the setæ are occasionally long, there are spiny and spineless forms, and there are variations in the scar band and scar line. When we consider the extremely primitive nature of *Dhaulu,* and its obvious resemblance to *Katha* in many particulars, there seems to be some justification for the expectation that a closer study will increase the number of these resemblances in some seedlings of *Saccharum spontaneum* to the Sunnabile series. There is thus some reason for tracing both of the primitive Punjab canes to a common ancestor, *Katha* from a red form and *Dhaulu* from a white, the differences in whose seedlings have been fixed and transmitted by the vegetative method of propagation.

The other groups of indigenous Indian canes have not as yet been subjected to the detailed comparative study accorded to the Saretha and Sunnabile classes. It is by no means impossible that, when this is done, similar resemblances may be detected. Judging from the single character, the mode of branching, it would seem that the Mungo and Pansahi groups are the more primitive, and that they fall into line with the Saretha class, while the Nargori group, as far as it has been studied, shows a formula more comparable with the Sunnabile series, a distinct advance towards the thick canes. *Khelia* and its allies are yet further developed, being intermediate in this respect between the Sunnabile and Nargori groups and the thick canes. We thus see that the study of merely one character *may* throw light on the various stages of development of Indian canes, and it is justifiable to assume that a comparative study of many characters will make the path plainer. The apparent absence of differences such as we have collected in this paper in the members of the Pansahi, Nargori, and Mungo groups may be due to their being more recent offshoots from the parent stem. Lastly, there are certain primitive canes growing in the Central Provinces which should be compared with *Saccharum spontaneum,* e.g., *Barahi* and *Katai.* The latter might lead to a connection with the Nargori group. So also *Shakarchynia* and *Kheri* in Bengal, which appear to be primitive forms,

and doubtless many more in parts of the country where as yet the cane varieties have not been collected. These points are merely indicated here to support the idea suggested that the careful study of minute vegetative differences may be of use in tracing the course of development in closely allied varieties of cultivated plants. The line of work with seedlings of each variety is more complicated, in that the minute vegetative differences relied on are ruled out, as they do not appear to be always inherited, but a study of the range of variation in each group will also assuredly assist in fixing the probable wild ancestor. Such work is already possible, with the mass of details collected in the descriptions of different Indian varieties, but it is not likely that there will be time available in the immediate future for working these details out. One point may, however, be mentioned in passing. We have now a certain knowledge of the relative stability of vegetative characters in the groups forming the subject of this paper. But it is unlikely that this will apply to the same vegetative characters in other groups, even if they are derived from the same wild form, and this makes it all the more necessary that each group should be separately studied in all its varieties.

We have thus far ignored the fact, which has come to light gradually in our study, that in the Saretha group there is a distinct subdivision into two sections, primarily separable by the colour of the stem, which may be roughly termed the brown and green stemmed sections. Each section contains a primitive Punjab variety and they have been named after these. The Katha section is characterized by the regularity of brown marks or colorations on the canes and the Mesangan section is devoid of these. *Katha* and *Mesangan* are similar canes in many respects, but the Mesangan group, although including a thin cane, consists chiefly of the thicker forms found in other parts of India than in the Punjab and neighbouring parts of the United Provinces. *Saretha*, which is the thickest variety in the Katha section, has a form in the Mesangan section also, sometimes distinguished as *Dhaun Saretha*. In the detailed study of these two sections, which is interpolated in many of the character studies, we shall see that the Mesangan section is in many respects intermediate between the Saretha and Sunnabile groups, and it may therefore be regarded as, on the whole, a more developed series, further from the original wild form.

In some of the characters used in separating the varieties and groups, it has been found difficult to state the differences succinctly, especially in such as involve complicated series of measurements. For the sake of clearness, certain empirical expressions have been introduced, and the rows of figures have been plotted as curves on squared paper. But, for these to have any general value,

it has been necessary to take a very large series of measurements, and this part of the work has been very laborious. For instance, on going through the varieties, it soon became evident that the organs in the Sunnabile forms were on the whole shorter and broader than in the Saretha varieties. As each series contained thick and thin, large and small varieties, it became necessary to include proportional measurements, and *modules* have been introduced founded on the length of the organ divided by its breadth, and this has given satisfactory results. But one was also soon convinced that the shape of the leaf was different in the two groups, and the module fails to indicate this fully. For the demonstration of this difference in shape, it became necessary to take a series of width measurements at different places up the leaf till the widest point was reached. The points fixed were the base, 1″ from it, and also 6″ and 12″ and the widest place, wherever that was. By studying these in each variety and averaging them in the whole group, we have been able to express the shape of the leaf by means of the *gradient* of increase in width, and this gives an expression of the general shape of the leaf. The width of the midrib was measured at the same places, for it was noted that this part of the leaf was much more prominent in the Saretha series (as in *Saccharum spontaneum*) than in the Sunnabile group, and it was desired to state this accurately.

Many of these measurements were undertaken, not so much to give exact data, as to convince one's self that an observed difference was actually present as a group character a matter of peculiar difficulty in varieties with such a wide range in general size and, if present, what exceptions were observable. The results are interesting, as indicating the relative closeness of the different varieties in the groups, for, generally, where exceptions occur, such are also traceable in other characters, and we see that in each group there are fluctuations in various directions, suggestive of new points of departure in the evolution of the type.

The variation in the length of organs at different periods of growth has received special attention, and it is hoped will form the subject of another memoir. The length of joint, for instance, is very different at the base, in the middle and at the top, and the two groups under consideration show marked differences in this variation; there is greater variation in the Saretha series, and the longest joints are always nearer the base than in the Sunnabile series, which is more uniform all through. But to put this down in definite terms was very difficult. In each variety 20 canes were taken at haphazard, and each joint, leaf sheath and lamina was measured in succession from base to apex. As the number of joints varies from cane to cane, it becomes an extremely

difficult thing to obtain an average series of the figures, and the general result of investigation seems to demonstrate that it is impossible to obtain an *average* cane, and therefore, in its place, an *ideal* cane has been built up for each variety and group in these respects. The results have been reduced to curves which show the differences sufficiently well, but it may be mentioned that some of these curves are based on as many as 10,000 individual measurements, and it becomes a question if this amount of labour is justified by the result. The answer to this question can only be obtained by an inspection of the curves reproduced, but, in a classification built up on a morphological study of vegetative organs in closely allied cultivated plants, one object is to build up a typical form characteristic of the variety and group, and it is not obvious how this can be otherwise accomplished. It is worth while drawing attention to the fact that, in the end, characteristic curves of the lengths of organs in different parts have been obtained in each case, whereby the mode of growth in the two groups is seen to differ somewhat widely. But the matter is complicated, and a special note has been drawn up on it, wherein the difficulties are fully discussed and the method of overcoming them described.

A note has also been written on *early and late* canes in each clump. This matter has been referred to in the two preceding Memoirs on Indian Sugarcanes, and in the present paper new light has been thrown on the subject by the dissection of cane stools and the study of the method of branching. Some fifty stools have been dissected out recently, belonging to twenty-four varieties of canes, and some of the results are interesting. The main point is that there is overwhelming evidence that the late canes are the thickest, thus reversing earlier conclusions drawn from the behaviour of the Punjab canes, late in the season.

The examination of non-measurable characters has also involved a great deal of work. So much so, that it has been found necessary to curtail the list of observed differences for lack of time to conduct the observations on the necessary scale. After all, such a thing as a complete analysis of the differences between any two living organisms or groups of organisms is obviously unattainable. The omission of a character does not therefore indicate that there are not differences in it. As already said, there are probably a great many more than those detailed in this paper.

Before proceeding to the enumeration of the characters, it is advisable to state on what material the present examination has been based. As each new variety is added to the collection at the Cane-breeding Station, it is the custom to make as full an examination of it as is possible before planting. Further,

fuller descriptions are then recorded year after year, when there is the time for it. There is thus a great mass of information available regarding the characters of varieties which have been growing for some years on the farm, and of course less for the newer importations. We are thus fairly well acquainted with many of the varieties dealt with in this paper, but, for the sake of comparison, we have mainly relied on studies in which all the varieties were grown on the same plot of land at the same time. Two such occasions have offered, namely, during the 1916 and 1917 cropping seasons. But the number of varieties in the classes under discussion grown in these two years differed a good deal in that a great many were added during the year, chiefly from the United Provinces and Bombay. The 1916 crop consisted of about eight varieties of the Saretha group and 10 of the Sunnabile. The canes were well grown, but the examination was taken up rather late, and many of them were obviously over-ripe, there were a large number of short joints at the ends of the canes and the leafy shoots were often injured, or flowering had taken place, with consequent shooting. For the better study of the leaf shoots, in which a great number of distinguishing characters were noted, it was decided to do the work over again in 1917, but at an earlier stage of growth. The varieties were therefore examined at about nine months. The numbers of varieties in the two groups had now considerably increased and there were 18 in the Saretha group and 15 in the Sunnabile. But the piece of land on which this crop was raised was not nearly so satisfactory, it was stiffer and more saline, and the general growth of the canes was poor. There were far fewer joints than could be accounted for by the youth of the plants, and the curves suffered accordingly. But the leafy shoots were healthy and the leaf characters were on the whole much more satisfactory. In most cases the results of the measurements in the two years are given separately, and it is interesting to note how well they agree, in spite of the great differences both in the varieties examined and the conditions under which the examination took place. This agreement is sufficiently striking in most cases to afford additional evidence of the justness of the classification.

The present Memoir is divided into the following parts :-

I. Introduction.

II. General list of characters dealt with, followed by a summary of the chief differences noted in the Sunnabile and Saretha groups, arranged in tabular form.

III. Note on the dissection of stools, as demonstrating the thickness of early and late canes and the relative systems of branching in the groups.

IV. Note on a method of building up an ideal cane for a variety or group by averaging measurements of the lengths of organs at successive joints.

V. Detailed list of characters in which differences have been noted, with tables of measurements for the individual varieties in the Saretha and Sunnabile groups.

For those desiring to obtain a general idea of the scope of the thesis and the conclusions arrived at, it will suffice to glance at sections I and II. The following sections contain an amplification of the same matter, with the details on which the conclusions are based. It was originally intended to add a section with detailed, illustrated descriptions of the individual varieties in the two groups, and I am indebted to several gentlemen for the kind way in which they have provided me with information regarding varieties grown in their Provinces. I would specially mention the Hon'ble Mr. Hailey and Rai Ganga Prasad Saheb of the United Provinces, and Mr. Evans in the Central Provinces. But the number of varieties has now increased so greatly, that it would take many months before this part of the paper could be prepared, and the notes received, together with my own descriptions, are filed in the office for working up whenever there is time to do this.

COIMBATORE,
19th May, 1917.

II. GENERAL LIST OF CHARACTERS DEALT WITH, FOLLOWED BY A SUMMARY OF THE CHIEF DIFFERENCES NOTED IN THE TWO GROUPS, ARRANGED IN TABULAR FORM. THE NUMBERS OPPOSITE THE CHARACTERS CORRESPOND WITH THOSE IN THE DETAILED LIST OF DIFFERENCES IN SECTION V.

List of Characters.

I. *General* -

Erectness of young shoots
Habit and mode of growth.
Tillering.
Dissection of stools.
Flowering.
Anthesis.
Seed production and seedlings obtained.
Number of dead leaves on the cane.
Length of cane bearing these.
Length of living leafy shoot.
Total length of plant.

II. *Cane* –

(1) Length of stripped cane.
Number of joints in the cane.
Average length of the mature joints.
Average thickness of the cane.
Cane module.
(2) Ovalness and thickness in different parts of the cane.
(3) Length of joints in different parts of the cane.

III. *Colour and markings of the cane*—

(1) General.
(2) Striping.
(3) Black incrustations.
(4) Bloom.
(5) Blackening.
(6) Corky markings.
(7) Colour of growth rings.
Colour of root zones.

IV. *Joint characters* -

(1) Groove.
(2) Circlet of hairs.
(3) Scar band and scar line.
(4) Growth rings.
(5) Root zones.

V. *Bud characters*—

(1) Bursting.
(2) Size.
(3) Form.
(4) Colour marks.
(5) Point of origin.
(6) Flanges.
(7) Bristles.
(8) Basal patches.
(9) Minute black hairs.

VI. *Leaf-sheath*—

(1) Colour.
(2) Bloom.
(3) Scarious border.
(4) Colour of young edges.
(5) Tuft of hairs.
(6) Spines on the back.
(7) Venation.
(8) Transverse bars.
(9) Ligular processes.
(10) Ligule.
(11) Clasping stem.
(12) Width at base.
(13) Width at apex.
(14) Length of mature leaf sheath.
(15) Sheath module.
(16) Number of sheaths on the cane.
(17) Length of sheath in different parts of the cane.

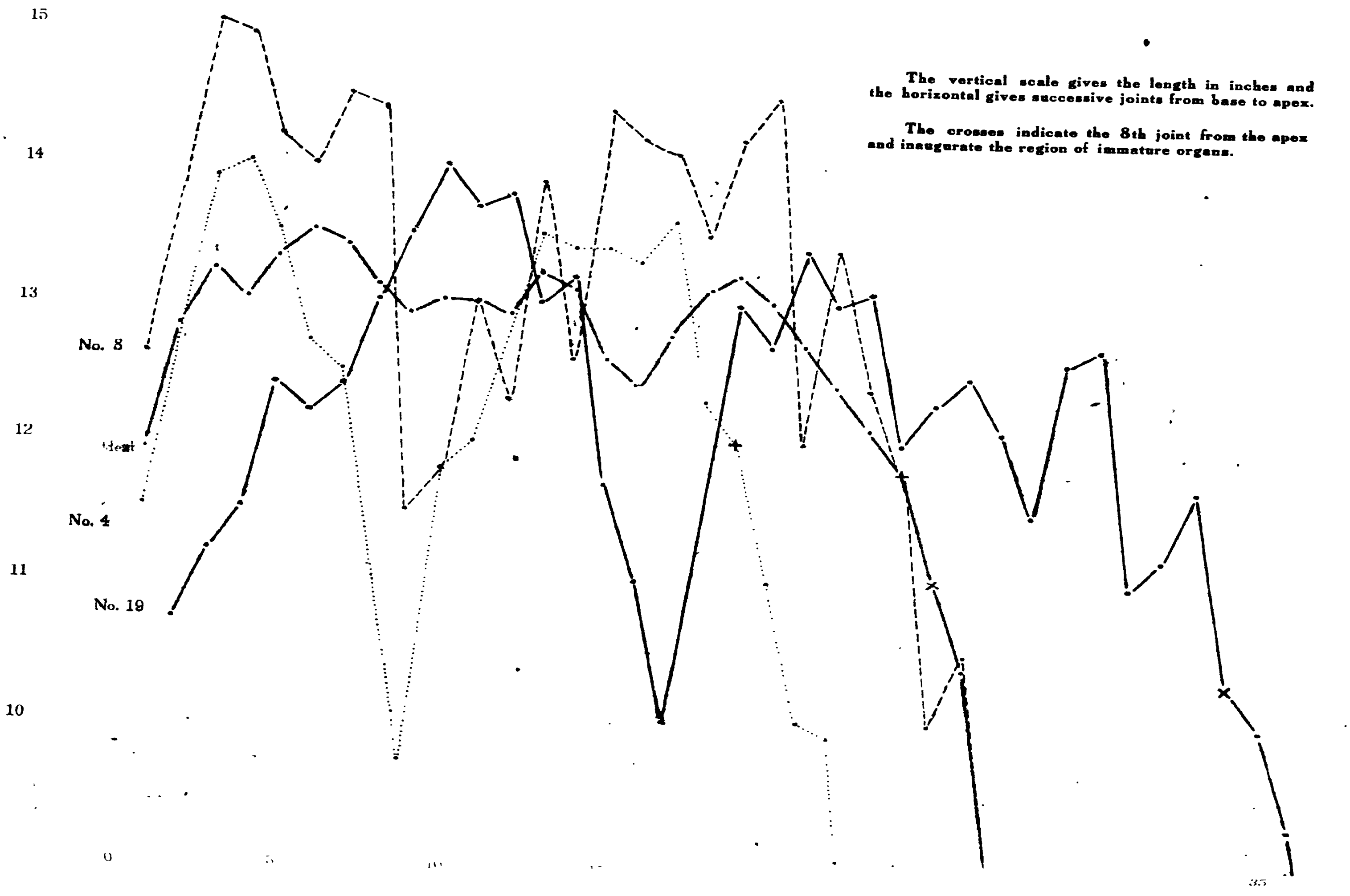
VII. *Lamina*—

(1) Channelling.
(2) Callus.
(3) Scabrous feel at the tip.
(4) Serrature.
(5) Number of laminas on the cane.
(6) Length of lamina in different parts of the cane.
(7) Average length of mature lamina.
(8) Width of leaf.
(9) Leaf module.
(10) Pinching in above the base. Position of widest part of the lamina. Gradients of increase and decrease in width.
(11) Width of midrib in different parts. Proportional width of lamina and midrib.

Summary of Differences in the Saretha and Sunnabile Groups.

The summary of differences, noted in the characters of the Saretha and Sunnabile groups of indigenous Indian canes, has been drawn up in tabular form. By this means a great deal of repetition is avoided, the statement gains in clearness and the various measurements can be more readily compared. In all cases, a fuller study is made in the detailed list given further on, and reference to it is invited to clear up doubtful points. Mention has been made

CURVES OF LENGTHS OF SUCCESSIVE LEAF SHEATHS IN KHARI CANES. THE 4th, 8th AND 19th IN THE PRECEEDING TABLE, i.e., THE SHORTEST, MEAN & LONGEST AS FAR AS NUMBER OF JOINTS ARE CONCERNED, AND THE IDEAL CURVE OBTAINED FROM THE AVERAGES OF THE WHOLE TWENTY IS ADDED IN RED.



The vertical scale gives the length in inches and the horizontal gives successive joints from base to apex.

The crosses indicate the 8th joint from the apex and inaugurate the region of immature organs.

in the Introduction of the observations on which these comparisons have been based. Although many of the varieties have been studied for several years, the present details are afforded by examination of the 1916 and 1917 crops grown on the Cane-breeding Station. It must be repeated that these crops differed in several important respects. The 1916 crop was studied when about 13 months old, it was well grown but rather over-mature. The 1917 crop was examined chiefly for leaf characters. It was about 9 months old and therefore immature, and the number of joints and leaves developed were accordingly fewer: but this latter difference was unfortunately emphasized by the fact that the crop as a whole was poorly grown, although apparently perfectly healthy, and this has led to a diminution in certain differences. The Sunnabile group forms a remarkably homogeneous class of canes, in spite of the fact that, in its range, it passes from some of the most primitive of cane varieties to thick, almost tropical, forms. The range is somewhat narrower in the Saretha series, but the variations met with in the group are considerably greater, so much so that it has been found possible to subdivide it into two sections. These are termed the Katha and Mesangan sections, distinguishable, in the first instance, by the presence or absence of a red brown coloration of the cane as it matures. It is interesting to note that, in many characters, there is a tendency for the Mesangan section to occupy a position intermediate between the Katha section and the Sunnabile group. But, in spite of this, the Saretha series, as a whole, is sufficiently uniform to separate it from the Sunnabile in the characters enumerated below.

Character	Saretha Group	Sunnabile Group
	I GENERAL	
Erectness of young shoots. They are much more erect in the Sunnabile series.	Very oblique, averaging 13–67 from the vertical at 4 months.	Averaging 5–30. *Puth Khaji* and *Mojorah* are, exceptionally, oblique.
Habit and mode of growth. This differs considerably in the two groups.	Spreading or sprawling; leaf tips often soon sharply bent at an angle.	Tending to straight, erect habit: leaf tips usually strict, erect, and, later, broadly curving.
Tillering generally greater in the Saretha series.	1917, 15 canes per stool.	1917, 12 canes per stool.
Dissection of stools .	Canes mature early and branching occurs to the fourth order.	Canes mature late and branching occurs to the third order.
Flowering much more abundant in the Saretha group.	Many varieties flower abundantly at Coimbatore.	Flowering is generally rare or absent.

Character	Saretha Group	Sunnabile Group
I. General—*concld.*		
Anthesis. Open anthers and good pollen present only in the Saretha group.	In all the varieties flowering some of the arrows show 80—90% of open anthers.	In all flowers the anthers are completely closed.
Seed production and seedlings obtained only in the Saretha series.	Any number of seedlings can readily be obtained from many of the varieties, especially the more primitive ones.	No seedlings have been obtained, excepting a batch from *Naanal* in 1913, but there is some doubt as to these.
Number of dead leaves on the cane. There are fewer of these in the Saretha series.	Average numbers— 1916, 23 1917, 15	Average numbers— 1916, 32 1917, 16
Length of the part of the cane bearing these dead leaves. It is slightly greater in the Saretha series.	Average measurements— 1916, 7′ 7″ 1917, 4′ 8″	Average measurements— 1916, 7′ 5″ 1917, 4′ 2″
Length of living shoot. This is greater in the Saretha series.	1916, 6′ 5″ 1917, 6′ 7″	1916, 5′ 11″ 1917, 5′ 11″
Total length of plant is greater in the Saretha group.	1916, 13′ 4″ 1917, 14′ 0″	1916, 10′ 1″ 1917, 11′ 3″
II. The Cane.		
Length of stripped cane. This is greater in the Saretha series.	Average measurements— 1916, 97 2″ 1917, 75 9″	Average measurements— 1916, 92·1″ 1917, 64·0″
Number of joints in the cane. This is greater in the Sunnabile series.	Average numbers— 1916, 33 1917, 26	Average numbers— 1916, 40 1917, 27
Average length of joint in mature part of cane. This is longer in Saretha series.	Average measurements— 1916, 3·9″ 1917, 3·8″	Average measurements— 1916, 2·9″ 1917, 3·0″
Average thickness of cane is greater in the Sunnabile series.	1916, 0·66″ 1917, 0·67″	1916, 0·73″ 1917, 0·77″
Cane module is much greater in the Saretha series.	Average numbers— 1916, 115 1917, 146	Average numbers— 1916, 87 1917, 119
Length of joints in different parts of the cane. This can be best seen in the curves on Chart II.	The Saretha joints are longer, but there are more of them in Sunnabile. The latter curves are therefore longer. The joints increase in length up the stem more rapidly in Saretha and reach an earlier maximum, and, after this is reached, they decrease more rapidly. The Sunnabile curve crosses that of Saretha towards the end because of the larger number of mature joints. There are, generally, greater fluctuations in the Saretha series, the length of joint being more uniform in the Sunnabile series.	

Character	Saretha Group	Sunnabile Group
III. Colour and Markings of the cane.		
General colour of the cane. There are considerable differences in this respect in the canes of the two groups, and in the Saretha group a sub-division is noticeable into brown and green sections.	Colour much obscured, in the lower parts, by weather and bloom and usually dirty here Brown, bone yellow, green or grey, occasionally light purple (brown covered by bloom) below, passing upwards to yellow, glaucous green, green yellow or grey, and finally to greyish or glaucous or whitish green or even white at the top, owing to excessive bloom. In the Mesangan section the browns are absent or extremely rare and, consequently, the joints are rarely light purple. The brown occurs in patches or streaks or as a general tone, and increases with age. It is therefore more marked in the mature canes	Brownish stone coloured or glaucous yellow, occasionally green below, passing upwards to clear light stone or greenish yellow, with distinct green patches at places where the cane is bent, finally to clear stone yellow, occasionally greenish yellow or dull green at the top *Putli Khajee* is a vivid grass-green cane, and *Ketari* has a general greenish tinge when compared with the rest. Many of the varieties have what are termed "white" canes, and this is reflected in their local names.
Striping is present in many canes. This is especially so in the Sunnabile series, and appears to be absent in the Katha section.	Not noted in the Katha section, but seen in four of the seven Mesangan canes.	Met with in all the canes of this group excepting *Dhaulu* (14 out of 15), as occasional faint purple lines
Black incrustations due to the out-growth and browning of epidermal cells, chiefly in the neighbourhood of the groove, only in the Saretha group.	Present in all, sometimes abundant and a striking feature in colouring.	Not met with in any variety.
Bloom is much more marked in the Saretha series.	Well developed, especially in the Katha section, where it is frequently very thick and copiously descending over the joint, especially in the upper part of the cane. It is less abundant in the Mesangan section. Bloom bands rather distinct, except where there is excess of bloom on the joint.	Not heavily developed and not descending much over the surface of the joint. Bloom bands not conspicuous on yellow joints. Quite sharp and distinct on the green joints of *Putli Khajee*.
Blackening caused by fungus attack on the bloom.	Moderately developed, rather faint and ill-defined, as if the surface had been smudged with soot	Well developed, in sharply isolated dense black patches.
Corky markings vary a good deal in different varieties, but there are general group distinctions.	In the main, short, fine, wavy lines, closely packed, but often not well developed.	More typically present. Usually as long, thick, parallel lines, rather widely separated and extending from the base of the bloom band about two-thirds of the way down the joint.

Character	Saretha Group	Sunnabile Group
III. Colour and Markings of the Cane—*concld.*		
Colour of growth rings generally stronger brown in Saretha.	Strong brown in the Katha section ; less distinct in the Mesangan.	Fainter brown generally, and most clearly seen in the middle of the cane.
Colour of root zones, brown cream below to lighter cream above and often bloomed.	Not blushing green in the Katha section, but occasional traces of this in the Mesangan.	Usually blushing green when exposed, and then showing the eyes as bright yellow spots.
IV. Joint Characters.		
Groove, a character apparently of prime importance.	Present or indicated in all varieties.	Not traceable in any variety.
Circlet of hairs, characteristic of the Saretha series	Usually well developed below and persistent at various parts of the stem.	Not usually present below or, if found there, soon disappearing upwards.
Scar band characterizes the Saretha series and scar line the Sunnabile.	Generally a scar band.	Usually a scar line.
Growth ring wider in the Saretha series.	Measurements in width— Katha section 0·11″ Mesangan section 0·14″	Measurements in width— Sunnabile group 0·08″
Root zone wider in the Sunnabile series and with a different arrangement of the eyes.	Katha section 0·22″ Mesangan section 0·25″ Eyes usually in 2-3 rows, more or less equidistant.	Average width 0·34″ Eyes in unequal rows, the lower being much larger and rather widely separated from the rest.
V.—Bud Characters.		
Bursting differs in the two groups.	Generally more or less apical	Usually dorsal.
Size. The buds are very small in both series, excepting in *Mojorah*. The amount of root zone covered by the bud gives a useful difference.	Average length— Katha section 0.23″ Mesangan section 0.27″. $\frac{\text{Root zone}}{\text{bud}}$ Katha section $\frac{22}{23}$, Mesangan section $\frac{25}{27}$	Average length 0·27″ $\frac{\text{Root zone}}{\text{bud}}$ $\frac{34}{27}$. In *Mojorah*, the thickest cane, the buds are rather large.
Form. There is little to choose here because of the smallness of the buds.	More pointed, ovate.	More rounded, oval or truncate.
Colour marks, consisting of brown blotches on greenish or yellowish bud.	Blotches of brown colour at the base and along the sides of the flanges.	Blotches of colour as two sharp brown lines at the top, like the head of an arrow.
Origin usually at the leaf scar in both, but a tendency to arise higher up in the Sunnabile series.	At leaf scar, especially in the Katha section, with a slight tendency to arise above it in the Mesangan section.	A marked tendency for the upper buds to arise higher up than the leaf scar.

Character	Saretha Group	Sunnabile Group
	V. Bud Characters *contd.*	
Flanges present a point of difference of some importance	Narrow outline usually obscured by bristles	Broad outline well seen and usually free from hairs
Bristles much better developed in the Saretha group	Fairly well developed and often abundant	Not well developed, irregular and often absent
Basal patches better developed in the Saretha group	Usually well developed and consisting of the typical crisped white parallel hairs	Usually poorly developed and often merely a roughness or pubescence. Well and typically developed in *Putli Khaje* and less so in *Ban*
Minute black hairs much better developed in the Sunnabile series	Practically absent in the Katha section but generally present in small numbers in the Mesangan section	Usually abundant in all parts of the bud
	VI. Leaf Sheath	
Scarious border commences early only in the Sunnabile series	Absent in the Katha section and very occasionally commencing early in the Mesangan section	Developing very early in the young leaf sheath
Young edges colourless in the Saretha group, soon becoming red brown in the Sunnabile	Light coloured or transparent in the young sheaths	Quickly assuming a red brown colour sharply contrasting with the green sheaths and often with a white border outside
Tuft of hairs at the apex of the sheath usually meagre, decurrent in the Sunnabile group	Not usually decurrent along the edges of the sheath in the Katha section, occasionally slightly so in the Mesangan section	Usually decurrent along the edge of the leaf sheath, sometimes very freely
Spines on the back present only in the Sunnabile group	Absent	Present or indicated in all but one of the two *Khadya* specimens examined
Venation finer and more distinct in the Saretha group	Usually well marked, clear and rather fine parallel lines in the Katha section, and moderately distinct in the Mesangan section	Irregular and often thickish and indistinct
Transverse bars present only in the Saretha group	Usually well developed in the Katha section though sometimes obscured by bloom. Less distinct in the Mesangan section	Usually absent or their place only indicated by small patches of darker colour
Ligular processes only present in the Katha section	Usually well developed in the Katha section as long, sharp teeth, seen poorly developed only in *Ganda Cheni* of the Mesangan section	Absent

Character	Saretha Group	Sunnabile Group
	VI. Leaf Sheath *contd.*	
Ligule. This is narrow in both groups although there appear to be differences. The setæ are very different	The middle portion usually widens out so as to form a small well defined lozenge. Setæ very minute irregular sparse and often absent	The upper and lower margins are more or less parallel and a lozenge is not present. Setæ strongly developed, usually longish and with isolated longer hairs in the middle
Clasping stem. The sheath clasps the stem more widely in the Saretha group. Measurements taken in terms of the circumference	1916 1.45 1917 Katha section 1.48, Mesangan section 1.43; average 1.46	1916, 1.35 1917, 1.39
Width at base. The sheath is wider at the base in the Sunnabile group	1916 3.09 1917 Katha section 2.79, Mesangan section 3.16; average 2.95	1916 3.37 1917 3.26
Width at apex also rather greater in the Sunnabile group but widest in the Mesangan section	1916 1.23 1917 Katha section 1.11, Mesangan section 1.40; average 1.22	1916 1.34 1917 1.30
Length of mature leaf sheath. There is little difference in the groups in 1917 but in 1916 the sheaths are longer in the Saretha one	1916 12.4 1917 Katha section 10.74, Mesangan section 13.84; average 11.95	1916 11.7 1917 12.0
Sheath module (length divided by width) is greater in the Saretha group	1916 4.0 1917 Katha section 3.8, Mesangan section 4.4; average 4.1	1916 3.5 1917 [illegible]
Number of sheaths in the cane greater in Sunnabile	1916 35 1917 29	1916 45 1917 30
Length of leaf sheath in different parts. This is best studied in the curve in Chart III	The curve resembles that of the length of joint. The average length and the extremes are greater in Saretha: there is a higher start, a more rapid rise and a steeper fall.	
	VII. Lamina	
Channelling. This is more marked in the Saretha series and the lamina takes part in it here	Marked especially in the midrib but the lamina takes part at the base especially in the Mesangan section	Not very marked and confined to the midrib
Callus shaggier and more marked in the Sunnabile series	Not well marked usually covered by waxy granules and often thinly pubescent or puberulous	Well marked with dense often shaggy pubescence and sometimes long hairs at the sides
Scabrous feel at the tip more marked in the Sunnabile group	Not marked either ventrally or dorsally	Strongly developed ventrally and less so dorsally

Character	Saretha Group	Sunnabile Group
	VII. LAMINA—*concld.*	
Serrature harsher and more persistent in the Sunnabile group.	Soft, fine, soon deciduous	Thick, harsh and persistent.
Length of lamina in different parts of the cane. This is best studied in the curves on Chart IV.	The curves agree with those of joint and sheath, in that those of the Saretha series are higher and shorter, and steeper at the ends, than in the Sunnabile group. The lamina curves differ from the other two in themselves, in that, once the region of full grown leaves is reached, the curves remain more or less flat for a considerable time.	
Average length of mature lamina is greater in the Saretha series.	1916, 4′ 5″ 1917, Katha section, 3′ 10″; Mesangan section, 4′ 2″ — average 4′ 0″	1916, 3′ 9″ 1917, 3′ 8″
Extreme width of leaf. This is considerably greater in the Sunnabile group.	1916, 1·5″ 1917, Katha section, 1·2″; Mesangan section, 1·5″ — average 1·3″	1916, 1·8″ 1917, 1·7″
Leaf module is considerably higher in the Saretha series.	1916, 35 1917, Katha section, 38; Mesangan section, 33 — average 37	1916, 25 1917, 26
Pinching in above the base is marked only in the Saretha series.	$\frac{\text{Width at base}}{\text{Width 1'' higher up}}$ 1916, $\frac{95}{79}$ 1917, Katha section, $\frac{84}{69}$; Mesangan section, $\frac{110}{94}$ — average $\frac{94}{78}$	1916, $\frac{103}{111}$ 1917, $\frac{[illegible]}{101}$
Position of widest part of lamina, as percentage of length up the leaf: it is lower in the Sunnabile group.	1916, 0·47 of length of lamina 1917, Katha section, 0·46; Mesangan section, 0·50 — average 0·48	1916, 0·40 1917, 0·41
Gradients of increase and decrease in width, up to and beyond the widest part. The gradients are steeper in the Sunnabile group.	Increase, 1917, Katha section, 1 in 100; Mesangan section, 1 in 109 — average 1 in 102	Increase, 1917, 1 in 55
	Decrease, 1917, Katha section, 1 in 48; Mesangan section, 1 in 40 — average 1 in 44	Decrease, 1917, 1 in 33

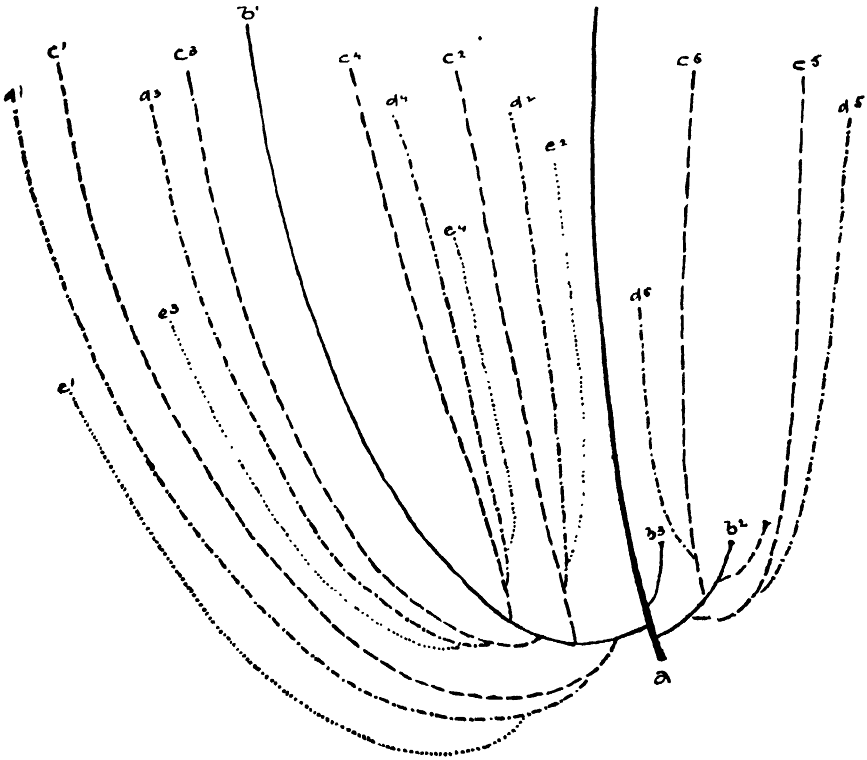
The midrib is more prominent in the Saretha series. It is not only wider in proportion to the rest of the lamina, but it is also intrinsically wider, although the leaves are narrower For details refer to the table in the Detailed List of Characters.

III. NOTE ON THE DISSECTION OF STOOLS, AS DEMONSTRATING THE SYSTEMS OF BRANCHING AND THE THICKNESS OF EARLY AND LATE CANES.

The presence of early and late canes in the same clump has been referred to in the two previous Memoirs,* and a further note may here be added. In the first Memoir it was noted that, in the 20 canes in which measurements of joint length were made at the Gurdaspur Farm (in 1913-14), there were in certain varieties two classes of canes, differing sufficiently widely to throw the curves of length into some disorder. After more study it was found that these two classes were formed at different periods of growth in the clump. The morphological characters of these two kinds of canes were summarized as far as possible. The first formed canes were seen to have more joints, to commence with shorter ones and to be on the whole thicker than those formed towards harvest time. It was inferred that there might be important differences in the richness of the juice, but no analyses were available. In the second Memoir chemical analyses were given of early and late canes, and it was seen that the former have uniformly richer juice. At the same time it was shown that, while certain varieties habitually develop these two kinds of canes, it is not so in others, and the presence or absence of early and late canes in a clump becomes a varietal or even group character of some importance. These results have been confirmed by further observations, except in one respect. It was noted in Gurdaspur that the late formed canes were thinner than those formed earlier in the year, and it was contended that the former had therefore nothing to do with the thick watery, mostly immature, canes which are seen in many clumps at crop time. In the varieties grown at Coimbatore the dissection of stools has shown that, as regards thickness, the position is reversed. The first formed canes have, it is true, more joints and these are on the average shorter than in the later ones, but there is a regular series of increases in thickness from the first formed cane to those of its successive branchings. The main cane is the thinnest, branches of the first order are thicker, those of the second thicker still, and so on. The undoubted fact that this does not apply to the early and late canes measured at Gurdaspur is thus anomalous, but it seems possible that the latter, being developed late in the season, at a time when growing conditions were unfavourable, may reflect this fact in their relative thinness. Further observations are however not at present possible there.

*Mem. 1, p. 38 and Mem. 2, p. 158.

I take as an example of this increasing thickness in late-formed canes one of the Pansahi group, as it has been demonstrated that the presence of early and late canes is a character of the whole of the cane varieties included in it. It will be remembered that, in the Punjab measurements, *Kahu* was chosen as showing early and late canes most typically, and this is a local member of the Pansahi group. Recent stool dissections of *Pansahi* (9 months old) are so instructive that a study of one example is appended below. The development of the branches of succeeding orders are so regular as to be almost mathematically exact. In the diagram, *a* represents the main shoot arising from the bud on the set. There are two branches of the first order, b^1 and b', and the former, larger branch, is the one here analysed. c^{1-6}, d^{1-6}, e^{1-6} are branches of the second, third, and fourth orders respectively. All the canes in the clump were full grown, excepting three *e*s, which formed strong shoots, cane-forming at the base and about five feet long. There were no other shoots than those in the diagram, which shows that the branching system was completed for the season.



BRANCHING SYSTEM OF A PANSAHI SHOOT FROM A SINGLE BUD.

The thickness of the branches (canes), at 2 feet from the base, was measured in each case, excepting the three *e*s which were only strong shoots five feet long, and here it was taken at the base. The figures in these three are on the high side, as in these late shoots the thickness of the stem diminishes slightly upwards.

Thickness of branches of successive orders in a *Pansahi* clump of canes, in centimetres:

								Average
a	1·42							*a* 1·42
b	1·79							*b* 1·79
c^1	2·00	c^2	1·86	c^3	2·00	c^4	1·90	*c* 1·92
d^1	2·63	d^2	2·24	d^3	2·31	d^4	2·26	*d* 2·38
e^1	(3·52)	e^2	2·69	e^3	(3·35)	e^4	(3·40)	*e* 3·29

There is no doubt but that the *e*s are, in this case, to all intents and purposes, "water shoots." Two photographs of another dissection of a Pansahi clump are appended (Plate III) which show this increase in thickness in the later branches very clearly.

It will be seen from the above that the late-formed shoots are branches of a high order and that they are uniformly thicker than the earlier ones. It is also very evident in the dissections that the joints of the earlier canes are shorter than those formed later. In the special case under consideration the average length of the joints in the lowest two feet of the branches of different orders is as follows: *a* 1″, *b* 2″, *c* 2″, *d* 2·8″, *e* 3″, and this difference is especially noticeable in the lowest part of each cane, namely, in the first formed or basal joints. The arrangement of the canes measured, in the tables of length of joint in different parts of the cane, where the cane with longest basal joint is placed first and those following are ones with successively shorter basal joints, is thus justified, in that, if there is any well marked division into early and late canes in the twenty measured in any variety, it will at once become evident (*cf.* page 30). From the study of a very large series of tables of measurements of all the joints in 20 canes of each variety, always arranged in this way, it may be stated, as a very general rule, that the canes with longer basal joints have, on the average, fewer joints, but it by no means follows that a definite division into two classes of canes, early and late, can be made at crop time. We have seen that such a division is definite in members of the Pansahi group. In other cases the transition from early to late cane is gradual. In the varieties dealt with in this paper, of the Sunnabile and Saretha classes, all the canes were spread out at crop time in 1917, and it was found

Dissected stool of *Pansahi*, nine months old. The main stem has a piece of white paper round it

Isolated canes of the same stool of different orders of branching: ***a***, main stem, ***b***, ***c***, ***d***, ***e***, branches of the first, second, third and fourth order respectiv

generally impossible to separate them into early and late, all the intervening stages being present. This would seem to indicate that, throughout the life of the plant, new canes are continuously being formed in these varieties.

In order to gain further information as to the cause of these differences in the canes of any one clump, a large number of stools of different varieties have been dissected out during the past season. One of these dissections has been detailed above and, among others, six varieties of each of the Sunnabile and Saretha groups have been dealt with. In the Saretha series, *Cheni*, *Chin*, *Hullu*, *Khari*, *Saretha*, and *Katha*, and, in the Sunnabile group, *Bansa*, *Bansi*, *Dhor*, *Kaghze*, *Sunnabile*, and *Naanal* were selected, and the dissections were analysed to see if there was any difference in their mode of branching. This work is to be regarded at present as preliminary, and it is intended to deal with the dissection of six varieties of each of the main classes of indigenous Indian canes on an extended scale during the coming season. The results thus far obtained appear to justify the idea that, by this study, light will be thrown upon the relative state of development of the different groups, as compared with the wild Saccharums on the one hand and thick, tropical canes on the other, these two forming the extremes of the series.

The adjoining table gives the results obtained for the Sunnabile and Saretha classes, in each case the most fully developed stools of those dissected being selected.

Dissection of clumps in six varieties each of the Saretha and Sunnabile groups (*a* being the main stem and *b*, *c*, *d*, *e*, branches of 1st, 2nd, 3rd, and 4th orders).

		Canes formed or forming					Shoots over 1 long				Shoots under 1 long				Bursting buds				Total canes	Total shoots and burst buds
		a	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*		
4 months old.	Saretha group	1·0	3·0	2·3	0	0	0	3·0	2·7	0	0·3	1·2	1·0	0	0	2·5	2·0	0	6·3	12·7
	Sunnabile group	1·0	1·5	0·2	0	0	0	4·0	2·0	0	1·0	3·0	1·7	0	0	4·8	1·2	0	2·7	17·7
9 months old.	Saretha group	1·0	3·4	5·4	2·7	0·3	0	0·3	0	0·7	0	0·3	0·3	0	0·5	2·3	7·0	0·3	12·8	11·7
	Sunnabile group	1·0	4·5	4·7	0·9	0	0	0·2	0·5	0	0	0·5	0	0	0	5·0	2·5	0	11·1	8·7

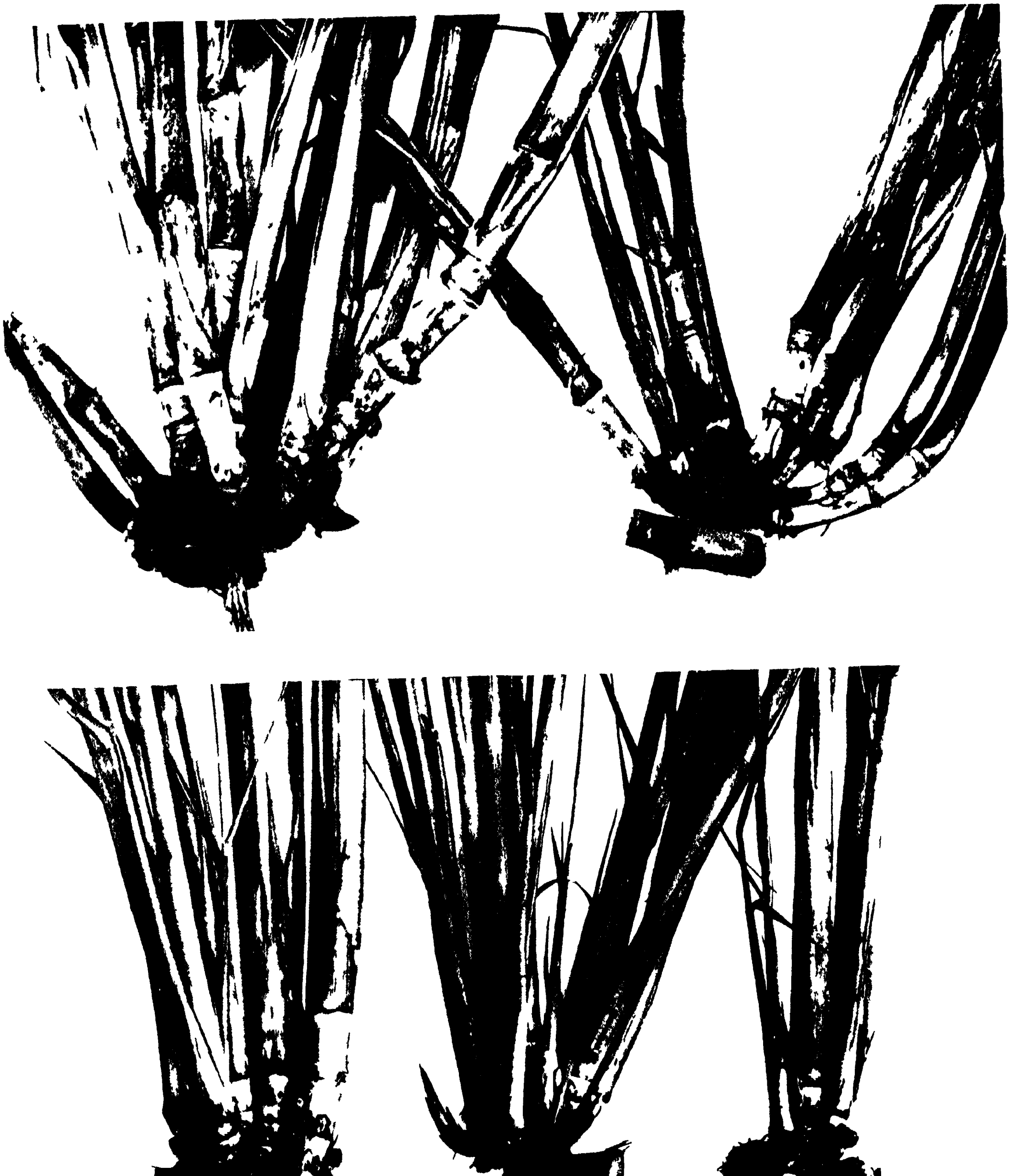
From this table the following interesting conclusions can be drawn :—

(1) The Saretha class of canes matures earlier than the Sunnabile, the number of canes forming at 4 months being 6·3 and 2·7 respectively. But

the Sunnabile group at this period shows a greater number of shooting buds the figures being 17·7 for Sunnabile and 12·7 for Saretha. I have selected *Saretha* and *Kaghze* stools, of the same age and dissected at the same time, to show the difference in rate of maturing. Photographs of the dissections are to be seen in Plate IV.

(2) The order of branching extends further in the Saretha group, branches of the fourth order being found in members of this series, whereas none are present in the Sunnabile varieties beyond the third order. This fact is of some importance as suggesting a more primitive character in the Saretha varieties, in that, generally speaking, the more primitive a cane, the higher the order of its branches. This will be clear from the following. The wild Saccharums dissected have canes formed of branches up to the fifth order, whereas the thick cane varieties are usually content with the second or third order. The groups of Indian canes fall between these two extremes, and I have constructed the following conventional formulæ for the clumps at maturity in each case :—

	a	*b*	*c*	*d*	*e*	*f*
Wild Saccharums	1	2	3	3	2	1
Saretha class	1	3	5	3	1	
Sunnabile class	1	5	5	1		
Thick, tropical canes	1	3 (1 ?)				



Dissected stools of two cane varieties, four months old, to show the rate of development of cane-forming shoots. The upper figure is of *Saretha*, two buds from one set. The branches are maturing much more rapidly than in *Kaghze* which is shown in the lower figure (three buds from one set.)

IV. NOTE ON A METHOD OF BUILDING UP AN IDEAL CANE BY AVERAGING MEASUREMENTS AT SUCCESSIVE JOINTS.

Averaging the length of the organs at successive joints of the cane presents many difficulties, the chief of which is that the canes are of different lengths and do not contain the same number of joints. Some of these difficulties have been alluded to in a previous Memoir* where it was decided that while six canes were insufficient for reliable averages to be obtained, measurements of twenty would at any rate demonstrate the presence of early and late classes of canes in the crop. The latter number has been adopted in all subsequent measurements, and a considerable amount of time has been devoted to the elucidation of the problem. This number is considered sufficient to rule out the occasional abnormal variations and, if the selection of canes is carefully checked, will, it is held, give fair averages from which the mode of growth can be ascertained. It is recognized that soil, manuring, rainfall and temperature, will have considerable influence, but if these are equal for all varieties, the intrinsic differences in growth will make themselves apparent in comparisons. It has transpired that environment has a considerable effect upon growth in length of the organs at different parts of the cane, and characteristic curves have been obtained in a series of canes grown at Taliparamba, on the west coast, and Samalkota, on the east coast, of the Madras Presidency. It is possible, from a glance at the curve of growth, to say at once in which of these two localities any variety has been planted. This fact makes it all the more necessary, in comparisons, to study all the canes at the same place and under the same conditions. We cannot safely compare the growth curve of one cane grown in North India with that of another grown at Coimbatore.

The twenty canes are chosen at haphazard, but the collector will obviously pass over such as are meagre and stunted, and the average will, therefore, be somewhat higher than in the whole crop. The object aimed at is to obtain twenty average canes which have become fully developed. When one considers that these twenty canes will vary greatly in general height, in the number of the joints and in other respects to be referred to below, it would seem well-nigh

* Mem. I, p 35

impossible to obtain fair averages of successive joints, but the results of the method here employed have this that is satisfactory, that the curves ultimately obtained exhibit considerable uniformity in each variety grown in the same place, and that there are well marked differences in the curves of different varieties, a study of which has added yet another character by which the Sunnabile and Saretha groups may be distinguished.

The organs measured are the joints (internodes), leaf sheaths and laminas. The twenty canes are cut at ground level and laid out on a table and the laminas are first measured in succession from the lowest joint upwards towards the apex, until a leaf is reached only 1 ft. in length. The sheaths of these leaves are next measured in the same way and the cane is then stripped, and the joints are measured until those are reached which are only one-tenth of an inch in length. In each separate joint the measurement is thus recorded of its own length and that of its leaf sheath and lamina, commencing with the lowest above ground and continuing until the youngest joints at the apex are reached. There are always three or four leaf organs measured in excess of joints, in that some joints less than one-tenth of an inch in length already have fairly long leaves, but the exact position of any leaf on the stem can be readily fixed by counting from the base upwards. All measurements are made with a foot rule divided into tenths of an inch.

In each variety we thus get detailed length measurements of the organs in twenty canes. The measurements of individual canes are then written in lines across the page, those of different canes being placed one above the other in vertical columns, all commencing with the joint immediately above the ground. They are thus arranged in a table, and in this table the cane with the longest basal joint is placed first, that with the next longest basal joint next and so on, a space being dropped between the first and last ten canes. The upper ten have longer basal joints and the lower shorter basal joints, and, if there is a marked difference in the number of joints in the upper and lower series, we have an indication that the variety is characterized by early and late canes.* The lengths of leaf sheath and lamina are treated in the same manner, the cane with the longest basal *joint* being again placed first, so that we have the twenty canes arranged in the same order in each series and can, at any moment, pick out from the tables the length of any joint and of its leaf sheath and lamina. We thus have ample material for the study of any correlations existing between the length of the joint and the organs belonging to it. (It may be pointed out,

* *See* previous section p. 26.

Fig 1 Cross bred bull (Montgomery cow × Ayrshire bull.)

Fig 2. Cross bred cow, Alibi No 3 (Montgomery cow × Ayrshire bull).

in passing, that other characters have been studied in the same twenty canes, *e.g.*, length of leafy shoot, width of leaf, thickness of cane in various parts, and the canes here too are arranged in the same order.)

The problem immediately before us is to construct an ideal cane as far as length of organs is concerned, representative of the twenty measured, and, for the purpose of illustration, I have selected the length measurements of the leaf sheaths in twenty *Khari* canes, given in the table at the end of this section. It will be seen from this table that, while there are 41 sheaths in one cane, there are only 26 in another, and that there are all gradations between these two extremes. The average number of sheaths in the twenty canes is 32, and, consequently, only this number of averages is required in the ideal cane. We obtain it in the following way. The last eight measurements are regarded as those of more or less immature organs, and, forming the close of the series, are retained intact. These are placed at the end of each line, blank columns being left for the inclusion of the whole 41 of the longest cane (No. 19). The last eight columns are thus present in all the canes, but the ninth from the end is only present in one cane, the longest. Working backwards, the next column is found in two canes, the 13th in four canes, and so on, until, at the 24th from the end, we again get all the canes represented. These two points, the 24th and 8th from the top of the cane, or the 18th and 34th from the base, are marked by arrows pointing towards one another. The averages of the columns between these two arrows are not truly representative, in that the shorter canes are left out, and, in those that have organs, these are at varying distances from the top, and they become less and less representative the further we proceed from base to apex. To bring the total number of measurements to 32, nine columns have to be left out, and the nine selected are those immediately preceding the last eight, as these measurements are taken from the smallest number of canes and are only representative of the longer ones. These nine columns are placed in brackets, and are no longer taken into consideration, and we are merely concerned in striking averages of the first 24 and last 8 columns. It will now be found that there may be a sudden break in the series from the 24th to the 25th column, namely, where the omissions have taken place. It is necessary to smooth out this break and make the fall to the last eight gradual. This is the first alteration which it is found necessary to make in the curve. But there is another point to be considered. In each series the lowest members are short, these are succeeded by longer and longer ones until a maximum is reached, after which a decline follows, until, in the terminal immature members, there is a rapid fall. As these maxima are reached at different points in

canes of different lengths, the process of averaging largely rules them out. And this question of maxima is complicated by the not infrequent appearance of second or even third and fourth maxima, as if there was a more or less defined periodicity in the growth in length of the parts. In the general summation, these secondary maxima are also mostly ruled out. This is a serious drawback, but, on the other hand, local, excessive variations, in individual canes, which may be due to many causes, are also ruled out, which is not such a disadvantage. It is thus quite possible to have a flat summation curve, in which the individual canes show several maxima and great individual variations from joint to joint. But these maxima should, as far as possible, be represented in the ideal cane, and their inclusion is one of the chief difficulties in our problem.

The following method, although somewhat arbitrary, has been designed to give each maximum when possible its value, it being inevitable that all of them are much less marked in the summation series than in the individual canes. In the table, each cane is studied as regards its maxima, and these are indicated by dots. Lines are then drawn between the maxima in adjoining canes, and dotted lines if the canes are not next to one another. By this system the general trend of maxima in the whole series can be seen at a glance. In the table given as an example, there is a certain amount of periodicity of growth, and three separate maxima are often present. The first six and the last ten canes of the table agree very closely in their periodicity. Attention is now paid to the summation series at the bottom representing the averages of the columns. If this series shows maxima in the right places, as judged by the rows of dots and lines, and this is not infrequently the case, the figures are left intact, providing that there is no sudden jump to the last eight immature members because of the removal of unrepresentative columns. If the maxima are not shown where they would be expected, or if there is an unjustifiable break in the curve just before the last eight, as is often the case, arbitrary alterations are made. But this is carefully safeguarded by making the alterations chiefly in the non-representative series between the arrows. The amount of actual change is, however, very little, as will be seen from the typical, but rather simple, case shown in the table. Two maxima are duly reflected in the average series (the second maximum representing the second and third of the individual canes merged into one), and it is merely necessary to alter a few numbers, so that there is a less sudden fall, in the figures, to the last eight, than is justified from a study of the whole twenty in this region.

Many summation series have been allowed to stand unaltered, in others the last few numbers have been altered to allow a reasonable drop to the last eight, in others it has been found necessary to emphasize a maximum or to indicate a late maximum by the increase of one or two figures in the non-representative columns. In doing this, it is borne in mind that the averages of a series such as this are much more uniform than the individuals comprising it, whether early or late, long or short, as explained above.

In obtaining the averages for the typical cane representing the whole Saretha or Sunnabile group, exactly the same procedure has been adopted, but, in place of the figures for individual cane varieties, the summation series of all the varieties are placed in the table, these varieties being of the same age and growing at the same place, under similar conditions. Similar precautions are taken as to the average number of organs, the position of the maxima and the smoothness of the series at the end. As will be seen in the sequel, the method is of service, in that, not only do varieties differ from one another in these series, but the whole groups of Saretha and Sunnabile forms show differences which are of value in distinguishing them.

But long series of figures are difficult to follow, and they have, accordingly, been plotted out in curves in which the characteristics of growth can be detected at a glance (Chart I). As examples of such curves, are appended those representing the lengths of leaf sheaths in *Khar*, in the shortest and longest canes (Nos. 4 & 19) of the twenty measured and in one which has the average number of joints (No. 8). Added to these is the ideal summation curve of the whole twenty canes examined. This latter is of mean length, is much more uniform than the curves of the individual canes, in that excessive variations from joint to joint have been ruled out, and the early and late maxima are indicated, although greatly reduced. The last few, immature organs are not all shown, and the crosses indicate where they commence. For other length curves, reference may be made to the paragraphs in Section V, dealing with the length of the several organs in different parts of the cane.

V. DETAILED LIST OF CHARACTERS IN WHICH DIFFERENCES HAVE BEEN NOTED, WITH TABLES OF MEASUREMENTS FOR THE INDIVIDUAL VARIETIES OF THE SARETHA AND SUNNABILE GROUPS.

The following is the list of cane varieties dealt with in this paper, with the locality from which they were obtained. They are arranged in groups, and the Saretha group is divided into its red and brown sections, and in each set the varieties with thinnest canes are placed first (as judged by one of the crop experiments in 1917). The varieties in the Sunnabile group are placed approximately opposite to those of similar thickness in the Saretha series. The names of places in brackets are those of the farms from whence the varieties were immediately obtained.

cm.	SARETHA GROUP *Katha* (brown) Section	cm.	SUNNABILE GROUP
1·3	*Raksi* (Shahjahanpur), Barabanki	1·3	*Tera*, Gurdaspur
1·4	*Katha*, Gurdaspur *Ramui* (Shahj.), Barabanki *Lalri*, Panipot	1·4	*Rakhra* (Shahj.), Barabanki
1·5	*Chin*, Aligarh *Channee*, Shahjahanpur * *Baraukha*, Cawnpore	1·5	*Ekar*, Jullunder *Dhaulu*, Gurdaspur
1·6	*Kansar*, Gurdaspur	1·6	*Kaghze* (Aligarh), Pilibhit *Ketari* (Sabour), Patna
1·7	† *Chynia*, Barah, N. Bihar *Burra Channee* (Shahj.), Bareilly		
1·8	*Saretha* (brown) (Partabgarh), Aligarh		

* There are many *Baraukhas* and this is, I fancy, a local Cawnpore name for a *Chin*-like cane grown there.

† This form is quite different from the *Chynia* around Pusa in Bihar, a form belonging to the Pansahi group.

cm.	SARETHA GROUP	cm.	SUNNABILE GROUP
	Mesangan (green) *Section.*		
1·4	*Mesangan*, Jullundor		
1·7	*Saretha* (green) (Jubbulpore), Aligarh *Jaganathia*, Barah, N. Bihar		
1·8	*Khari* (Sabour), Burdwan	1·8	*Bansa* (Sabour), Manbhum
1·9	*Hullu Kabbu* (Hagari), North-western part of Madras	1·9	*Bansi* (Nagpur), Bombay *Sunnabile* (Jubbulpore), Bombay
2·0	*Ganda Cheni*, Mysore	2·0	**Putli Khajee* (Barah), Assam ?
2·1	*Kalkya* (Manjri), Bombay	2·1	*Khadya* (Manjri), Bombay *Naanal*, Tanjore *Holle Cheni*, Mysore
		2·2	*Dhor*, Seoni, Central Provinces
		2·6	*Mojorah* (Jorhat), Assam

* The origin of this cane is obscure. It was obtained as an Assam cane at Barah estate in Bihar, but the Assam Agricultural Department have not met with it. It is a very distinct cane.

A study of this list brings out two facts. In the first place, the thinner canes, generally, are found in the Punjab and United Provinces, and we come across thicker varieties as we pass south-east to Assam and down the Peninsula. Secondly, the Saretha group has the largest proportion of its members in the first named Provinces, being absent or only occurring sporadically in Bengal, Assam, and the South. The Sunnabile group, on the other hand, has its greatest development in the latter tract and occurs only sporadically in the United Provinces. It is interesting to note that each group is fairly well represented by a few primitive forms in the Punjab. The order of arrangement, according to the thickness, here given, will be followed in the tables at the end.

Erectness of Young Shoots.

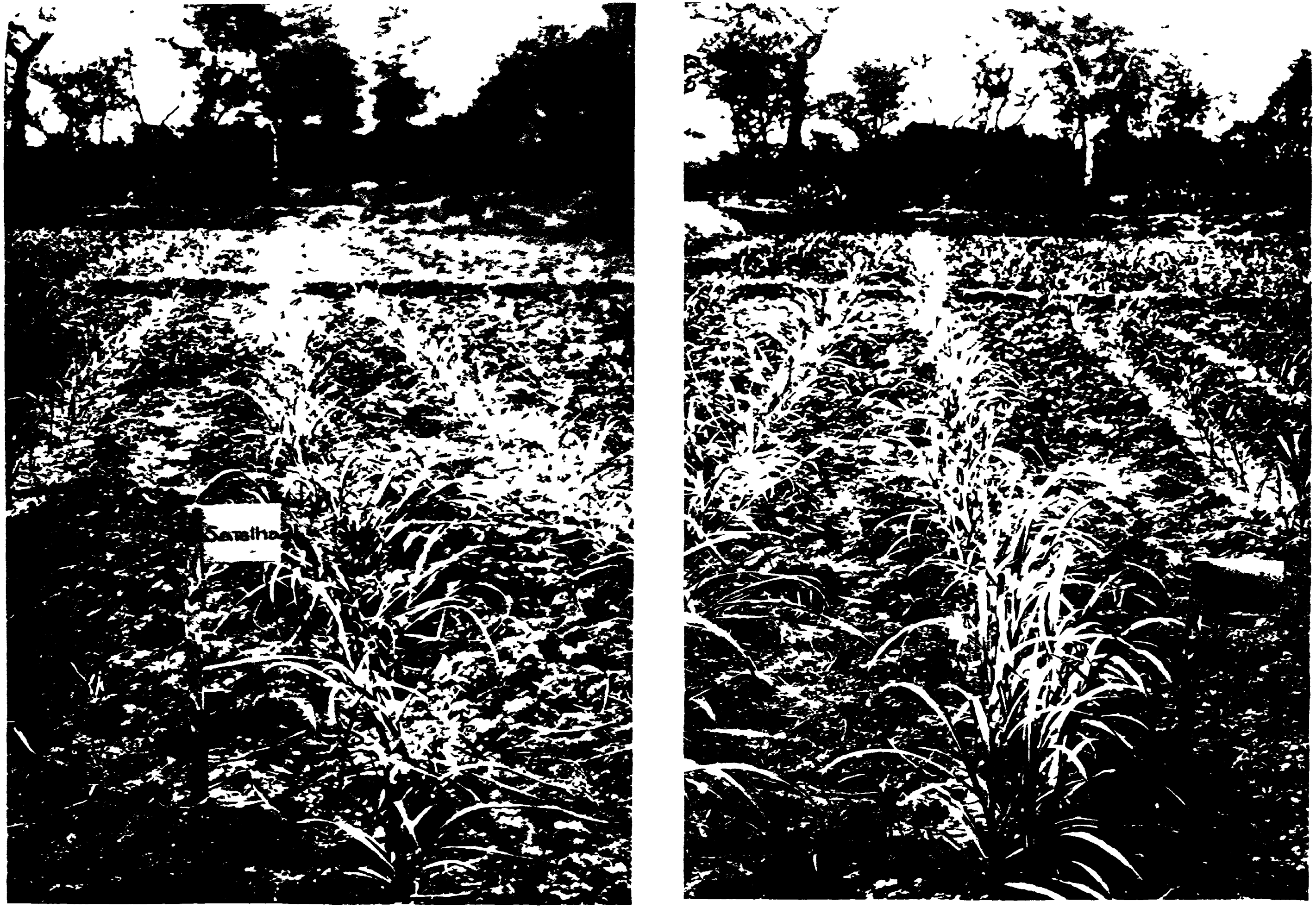
There is a marked difference in the Saretha and Sunnabile groups in this respect. Considerable attention has been paid to this character for several years past, in the study of varieties and seedlings grown in the Cane-breeding Station. Observations have demonstrated that it is a stable character in the varieties and that it is inherited by seedlings from their parents (*Mem.* 2,

pp. 36-39). *Saretha* and its class are characterized by considerable obliqueness in the young shoots, approaching *Saccharum spontaneum* in this respect, where, on any river bank, numerous seedlings may be seen which are at first perfectly flat on the ground. The members of the Sunnabile group, on the other hand, tend to produce rather erect young shoots. Observations were made on all the indigenous Indian varieties growing on the farm in 1915-16, when the plants were 5-6 months old, and figures have been extracted for the varieties now being considered. In each row of young canes the deviation of the shoots from the vertical was measured by a clinometer, such as is used in measuring the dip of strata in geology. Two figures are recorded for each variety and indicate the extremes met with. For example, *Naanal* 0°—25° means that, while some of the shoots were vertical, the greatest deviation of the shoots from it was 25°. Taking the two series and striking averages, 14 members of the Saretha group gave 13°—67° against 5°—30° for the 12 Sunnabile varieties measured, the extremes in the two groups being 10°—80° and 0°—45 respectively. This character is not an *absolute* one, and there are cases of overlapping. *Putli Khajee* and *Mojorah*, for instance, in the Sunnabile group, are distinctly oblique (Plate V).

Habit and Mode of Growth.

The Sunnabile and Saretha groups differ a good deal in general appearance in the field, although this character is not easily reduced to measurement. It is, moreover, difficult to determine the exact period when comparative observations should be recorded. These thin varieties, when grown in a few rows, soon require propping to keep them in their respective plots, and as soon as this is done all observations as to habit have to be given up. An exact study of habit has thus been largely precluded on the Cane-breeding Station.

The Saretha varieties are generally characterized by a spreading if not sprawling habit, the outer branches extending widely over the plot, and the growth is irregular and untidy (Plate VI). It is easy, on the other hand, to keep Sunnabile varieties within the limits of their plots; there is a tendency to a strict, erect habit and the branches at the base are closer together. In this, as in other respects, the Saretha series resemble *Saccharum spontaneum* in their habit. And this relative erectness of the two groups is emphasized by the character of the leaf tips. In the description of Punjab canes (*Memoir* 1) it was noted that the leaves of *Katha*, *Saretha*, *Kansar* and *Lalri* soon became bent at a sharp angle near the end, whereas this character was absent in *Dhaulu*.



Erectness of young shoots. On the left, *Saretha* has widely spreading, oblique shoots and, on the right, *Naanal*, of the Sunnabile group, has shoots more or less erect On the left of the *Naanal* row is another of *Saretha*

The whole series of Saretha varieties grown on the Cane-breeding Station.

The *Chin* plot with branches bending towards the observer

THE SPREADING HABIT OF THE SARETHA GROUP.

Fig. 1

Fig. 2

Habit and mode of growth. Fig. 1. *Saretha* and Fig. 2. *Sunnabile* as types of their respective groups. In the former the habit is sprawling (towards the observer) and the leaf tips are bent. In the latter the growth is strict and the leaf tips are erect.

These appearances seem to be more or less general in the groups. The varieties in the Sunnabile group generally have strict, bayonet-like leaf ends, and when the leaves bend, they do so in a broad continuous curve. This character of the leaf ends adds not a little to the general strictness of habit of the group, as contrasted with that of Saretha (Plate VII).

TILLERING.

The indigenous canes of India are well known to have much greater tillering power than the thicker canes of the tropics and, in well grown clumps, as many as fifty canes are by no means uncommon. All the varieties grown at Coimbatore in the two groups were examined with regard to this character at crop time, but this related only to *canes*, the shoots not yet forming canes being omitted. Another observation was, however, made for a different purpose in which all the shoots above one foot in length were counted in five members of each group.

(1) Each varietal plot consisted of three rows, twenty feet long, and there were ten stools in each row. Owing to other demands, only one row (that is ten clumps) was available for cane counting at harvest. The figures obtained were generally low, owing presumably to the poor growth in the plots during this season. The Saretha class, generally, had more canes than the Sunnabile. The greatest number of canes was found in *Raksi* (27 per clump), while *Ramui* and *Burra Chunnee* followed with one less in each. In the Sunnabile group, the greatest number of canes was found in *Bansa*, where there were 17. Several varieties of each series were specially poorly grown or destroyed by rats, but the general tendency was marked. The average number of canes per stool was 15 in the Saretha group and 12 in the Sunnabile.

(2) In connection with another piece of work, the canes and shoots over one foot in length were counted in a series of varieties during each month of the growing season, the last counting taking place just before harvest. In this series five of the Saretha and five of the Sunnabile groups were included, besides varieties belonging to other groups. The following are the results of the last counting.

Saretha series: *Chin* 29, *Saretha* 28, *Khari* 24, *Hullu Kabbu* 22, *Ganda Cheni* (poorly grown) 16.

Sunnabile series: *Kaghze* 20, *Bansa* 18, *Sunnabile* 17, *Naanal* 15, *Dhor* (poorly grown) 12.

The average numbers of canes and shoots over one foot in length in the two series were 24 and 16 respectively. But certain other points may be noted in these figures. It will be seen, if reference is made to the list of varieties at the commencement of this section, that in each series the amount of tillering is the exact converse of the thickness of the cane in the variety, that is, the thicker canes have fewer branches. Also, the thicker varieties of the Saretha group, *Khari, Hullu Kabbu* and *Ganda Cheni*, belonging to the Mesangan section, are intermediate between *Chin* and *Saretha*, belonging to the Katha section, and the Sunnabile group.

We are justified by the figures in stating that the tillering of the Saretha group is greater than that in the Sunnabile, and this result is in accordance with the idea already expressed that the former group contains more primitive varieties.

Dissection of Stools.

The mode of branching appears to differ in the Sunnabile and Saretha groups. This has been demonstrated by a dissection of the stools in six varieties of each group, and the branching is seen to extend to a higher order in the latter group. For a discussion of this difference, reference may be made to the preceding special note on the subject (Section III).

Flowering, Anthesis, Seed-formation.

There is perhaps no character in which the Saretha and Sunnabile groups differ more widely from one another than in their frequency of flowering, the proportion of open anthers found in the arrows and the ease with which seedlings can be raised from them. The following are the results obtained during the exceptionally favourable season of 1915-16, when 35 indigenous Indian canes flowered on the farm. *Saretha, Lalri, Katha, Kansar,* all flowered profusely, a matter of special interest because I believe that the last three, being Punjab canes, have never been known to flower before. In the same group, *Chin, Baraukha, Hullu Kabbu, Khari, Mesangan* and *Cheni* also flowered. In each of these ten varieties some at least of the arrows had over 90% of the anthers open. Between 3,000 and 1,000 seedlings were obtained from them, but this number could easily have been multiplied ten times if it was thought advisable to do so. It may be mentioned that, in North India, a few canes flower sporadically every year and these are usually *Khari* and *Saretha* of this group, and they are practically the only canes which do so, as it has been found safe, when noting cane arrows in a plot, to assume that either *Saretha* or *Khari* is present. Turning to the Sunnabile group, *Dhor* and *Kaghze* flowered

in 1915-16; none of their stamens were open and, in the pans sown, not a single seedling germinated. None of the other members of the group flowered. The capacity for flowering and the fertility of the arrows would thus appear to be an important character in the separation of the two groups.

Since writing the above, the 1916-17 results have become available. In the Saretha group, *Katha, Lalri, Mesangan, Kansar, Chin, Chunnee, Saretha* (green) and *Saretha* (brown), *Hullu Kabbu* and *Ganda Cheni* flowered. The last named had 62% of anthers open in the arrows and all the rest over 80%. *Hullu Kabbu* and *Ganda Cheni* did not produce seed which germinated but, wherever the others were sown, they produced masses of seedlings. In the Sunnabile group, *Dhaulu, Ekar, Hotte Cheni, Kaghze, Putli Khajee* and *Mojorah*, all produced a few arrows, but in none of these were any of the anthers open and no seedlings were obtained in the pans sown. Here too, then, the thicker members of the Mesangan group showed an approximation to the Sunnabile group.

NUMBER OF DEAD LEAVES, LENGTH OF CANE BEARING THEM, LENGTH OF LIVING SHOOT, AND TOTAL LENGTH OF PLANT.

The general height of canes in the field is not readily discernible in small plots where the plants are grown in a few rows. The heavy nodding masses have to be supported, and, this being especially the case with thin varieties, they lose more of their height than the thicker ones. But certain observations have been recorded which give us information on this point in an indirect way. These observations are detailed in the heading of this section, twenty canes being carefully measured in each variety as usual. In the 1915-16 crop, seven varieties of the Saretha group and ten of the Sunnabile were thus studied before the plots were destroyed. But the canes had been over twelve months in the ground, the plants were overgrown and the end portions were twisted and shooting, so that the leafy shoots were frequently drying and irregular. It was accordingly decided to repeat the observations on the 1916-17 crop at an earlier date, especially as a much larger number of varieties had been separated out as belonging to the two groups. Eighteen members of the Saretha group and fifteen of the Sunnabile were examined when about nine months old, and the leafy shoots were intact and vigorous, while the canes were still comparatively straight. But in this case, as noted elsewhere, the growth in many of the varieties in both sections was very poor and the figures must be considered as distinctly below the average. In spite of these drawbacks, the general agreement of the proportional figures in the two sets of observations justifies the belief that there are real differences in the Saretha and Sunnabile groups

in the characters mentioned. This may be seen from a study of the appended table.

		Number of joints with dead leaves		Length of part of cane with dead leaves		Length of shoot with living leaves		Total length of plant	
		Extremes in the group	Average	Extremes in the group	Average	Extremes in the group	Average	Extremes in the group	Average
1915-16 ovor-ripe	Saretha group	21—23	23	6′ 11″—8′ 2″	7′ 7″	5′ 8″—7′ 1″	6′ 5″	13′ 2″—15′ 1″	14′ 0″
	Sunnabile group	29—38	32	6 10″—9 1″	7′ 5″	4 4″—6′ 11″	5 11″	11′ 4″—15′ 2″	13′ 4″
1916-17 9 months old	Saretha group	12—17	15	3′ 3″—5 5″	4′ 8″	5′ 2″—8′ 0″	6′ 7″	9′ 7″—13′ 2″	11′ 3″
	Sunnabile group	13—20	16	2 9″ 5′ 7″	4′ 2″	4′ 4″—7 1″	5′ 11″	7′ 8″—12′ 5″	10′ 1″

It appears from the table that, at any given period, there are more joints with dead leaves in the Sunnabile group, but, in spite of this, the portions bearing these dead leaves are longer in the Saretha series. From this it appears that the lower joints are longer in the Saretha group. In the dead leaf portion, at twelve months or over, 23 Saretha joints measure 7′ 7″ while 32 Sunnabile only reach 7′ 5″, while at nine months 15 of the former measure 4′ 8″ while 16 of the latter only reach 4′ 2″. Further, the living leafy shoot is uniformly longer in the Saretha series by 6″ or 8″, and thus we are prepared for the independent results obtained in the measurements of the total lengths of the plants of the two series laid out on the ground. At crop time the average length of the Saretha series was 14′ 0″ to 13′ 1″ for the Sunnabile series, while the difference was greater at nine months when the figures were 11′ 3″ and 10′ 1″ respectively. These results tally with those given later, when it is shown that the average cane, joint and leaf are longer in the Saretha group than in the Sunnabile series.

Cane Measurements.

(1) *Length of stripped cane, number of joints, average length of mature joints, average thickness of cane, and cane module.*

These characters have been noted at various times and in various places, but, for the sake of comparison, two only of these sets of observations will be

considered here, in that the varieties were grown together in adjoining plots under similar conditions. The first set of figures was obtained in the 1916 crop when seven of the Saretha and 10 of the Sunnabile groups were measured and the second was obtained in the 1917 crop when 18 of the Saretha and 15 of the Sunnabile group were grown. The measurements are summarized in the following table, where in each variety 20 canes were measured in detail from ground level to the young growing point.

Average cane measurements in the Saretha and Sunnabile groups.

	SARETHA GROUP		SUNNABILE GROUP	
	1916 crop 13 months old 7 varieties	1917 crop 9 months old 18 varieties	1916 crop 13 months old 10 varieties	1917 crop 9 months old 15 varieties
Length of stripped cane ..	97·2″	75·9″	92·1″	64·0″
Number of joints .	33	26	40	27
Average length of mature joints	3·9″	3·8″	2·3″	3·0″
Average thickness of cane	0·67″	0·66″	0·77″	0·74″
Cane module ...	146	115	119	87

The length of stripped cane, from ground level to the first joint at the apex one-tenth of an inch in length, is constantly greater in the Saretha series, whereas the average number of joints is as constantly less in this group. It is not therefore surprising to note that the average length of mature joints (omitting the last eight, immature ones at the apex) is greater in the Saretha than in the Sunnabile group.

The thickness of cane has been averaged as described in the next paragraph, and there is a close approximation between the results obtained and those taken more casually, in a general survey of the whole of the canes of each variety at crop time, when they were laid out on the ground. The canes of the Sunnabile group are, on the average, thicker than those of the Saretha series. And this fact, taken with their comparative shortness, causes the cane module (length divided by thickness) to show a greater difference still. The cane module is much higher in the Saretha group, indicating that, as a class, the canes are thinner and longer than those of the Sunnabile varieties.

(2) *Ovalness and thickness in different parts of the cane.* The estimation of these is based upon the same series of measurements. To obtain the

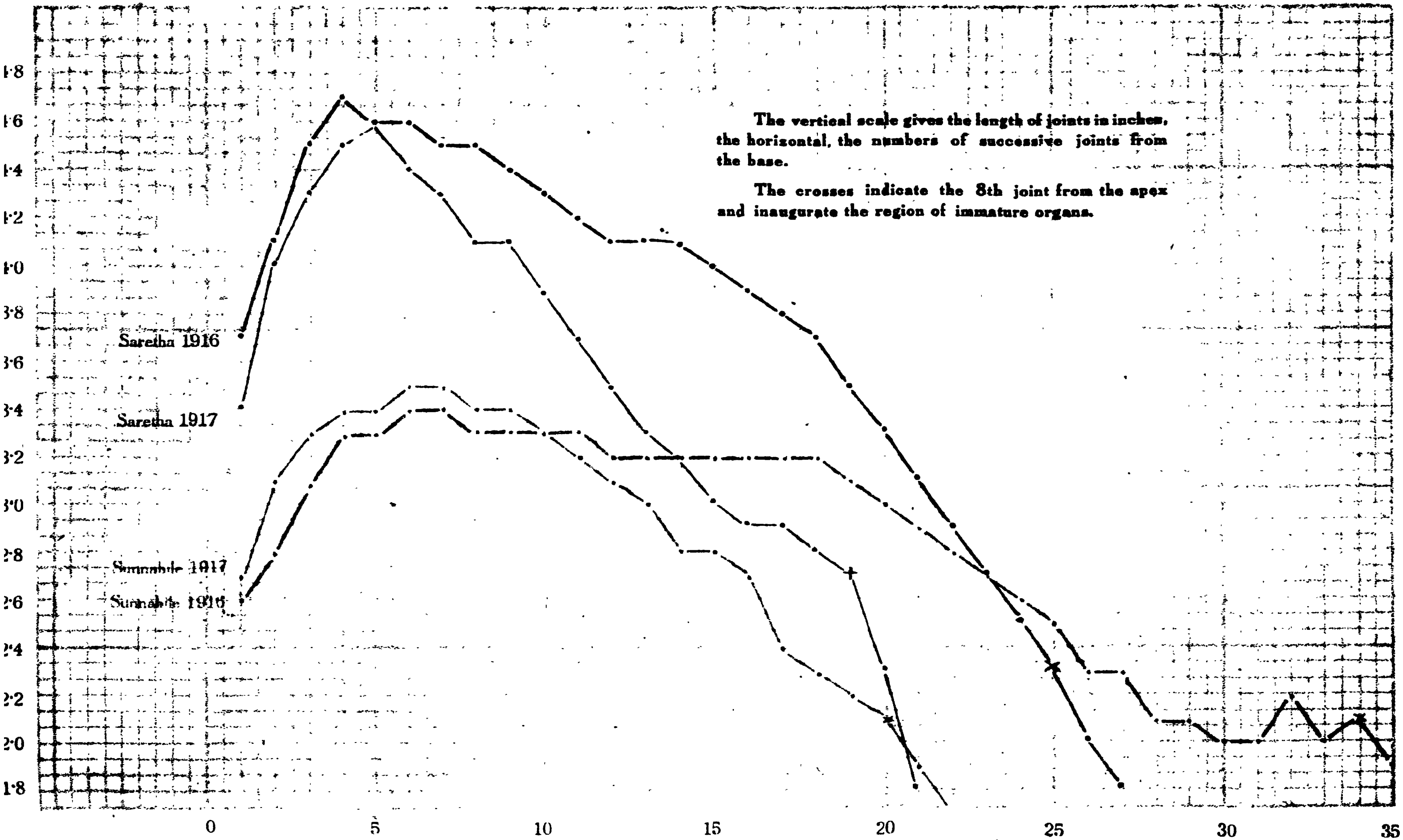
thickness, each cane is measured in three places, at the base, in the middle and at the highest mature joint, and these measurements are made, by means of calipers, in two directions, median or in the plane of the bud, and lateral, or at right angles to it.

	Saretha Group		Sunnabile Group	
	1916 crop cm.	1917 crop cm.	1916 crop cm	1917 crop cm.
Base	1·60-1·69	1·67-1·72	1·85-1·93	1·83-1·90
Middle	1·66-1·74	1·70-1·75	1·88-1·99	1·88 1 96
Top	1 63-1·70	1·51-1·56	1·89-2·03	1·67-1·75

Of these figures the first is always lateral, and it is seen that ovalness is a constant character, the median thickness being always greater than the lateral. There is little difference beween the two groups in ovalness, but Sunnabile canes are slightly more so than Saretha. It was noted in examining the canes that a few of the thinner Saretha varieties had almost cylindrical canes--a rather rare phenomenon and this probably accounts for the difference in the averages. As to thickness in different parts, at nine months, the middle of the cane is thickest, then the base, while the apex is thinnest. This thinness of the apex is less pronounced in the mature canes (1916 crop) and, indeed, conditions are reversed and the apex is thicker than the base in both series. This is especially noteworthy in the Sunnabile series, where the apex is thickest in ripe canes and the base the thinnest. Thickening of the apex in Indian canes is by no means an unusual character, and it is probably the Saretha series rather than the Sunnabile which is exceptional in this respect.

(3) *The variation in the length of joint in different parts of the cane* can best be studied in the accompanying curve, in Chart II, which represent a summation of the curves of all the varieties in each group. As before, there are two sets of measurements, those of the 1916 and 1917 crops, and in each case 20 canes were taken in each variety and the length of successive joints measured from ground level to the apex, until a joint only one-tenth of an inch was reached. It will be obvious that the preparation of these curves has entailed a very considerable amount of labour. To measure the joints in a variety whose 20 canes average 32 joints each, means 640 individual measurements, and the summation series of 7 such varieties means 4,480 measurements. The Sunnabile curve of 1916 is based on 8,200 measurements, while that of the 1917 series is the result of a yet greater number of measurements.

CURVES SHOWING THE AVERAGE LENGTHS OF SUCCESSIVE JOINTS FROM BASE TO APEX, IN THE SARETHA AND SUNNABILE GROUPS IN THE 1916 AND 1917 CROPS.



The following are the average lengths of joints of Saretha and Sunnabile in the two seasons, in inches:—

1916 crop. Saretha series. 7 varieties. 3·7, 1·1, 1·5, 1·7, 1·6, 1·6, 1·5, 1·5, 4·1, 4·3, 1·2, 1·1, 4·1, 4·1, 4·0, 3·9, 3·8, 3·7, 3·5, 3·3, 3·1, 2·9, 2·7, 2·5, 2·3, 2·0, 1·8, 1·5, 1·0, 0·5, 0·2, 0·1.

Sunnabile series. 10 varieties. 2·6, 2·8, 3·1, 3·3, 3·3, 3·1, 3·1, 3·3, 3·3, 3·3, 3·3, 3·2, 3·2 3·2, 3·2, 3·2, 3·2, 3·2, 3·1, 3·0, 2·9, 2·8, 2·7, 2·6, 2·5, 2·3, 2·3, 2·1, 2·1, 2·0, 2·0, 2·2, 2·0, 2·1, 1·9, 1·7, 1·4, 0·8, 0·4, 0·2, 0·1.

1917 crop. Saretha series. 18 varieties. 3·1, 1·0, 1·3, 1·5, 1·6, 1·1, 1·3, 1·1, 4·1, 3·9, 3·7, 3·5, 3·3, 3·2, 3·0, 2·9, 2·9, 2·8, 2·7, 2·3, 1·8, 1·4, 1·0, 0·5, 0·2, 0·1.

Sunnabile series. 15 varieties. 2·7, 3·1, 3·3, 3·4, 3·4, 3·5, 3·5, 3·4, 3·4, 3·3, 3·2, 3·1, 3·0, 2·8, 2·8, 2·7, 2·4, 2·3, 2·2, 2·1, 1·9, 1·7, 1·3, 0·8, 0·4, 0·2, 0·1.

But these figures convey comparatively little to the mind, and they are accordingly plotted out in curves where the black lines refer to the Saretha and the red ones to the Sunnabile group. The thinner lines, in each case, refer to the nine months (1917) crop, and the heavy lines to the fuller grown 1916 crop.

(4) *Curves.* The two Saretha curves resemble one another in their high commencement, their rapid ascent and steady decline after an early maximum. The Sunnabile curves, on the other hand, start lower, have a more gradual ascent to a lower, later maximum, are more tardy in their descent and ultimately cross the Saretha curves. The curves are lower, flatter and longer in the Sunnabile series. In the Saretha series, the joints are longer at the base and rapidly increase in length to the 4th or 5th joint, after which they steadily decline to the apex. In the Sunnabile series, on the other hand, the basal joints are of average length, they become longer upwards till the 6th or 7th joint and after that gradually decrease in length, with occasional sections in which succeeding joints are of equal length. There are more joints in the Sunnabile series, so that before the immature, apical joints are reached, they overtake the Saretha series and are at the end longer than these. In the 1916 canes the 23rd joints are equal and the succeeding ones in the Sunnabile curve are longer, to the end. These general characters of the curves of joint length

in the two groups of canes should be borne in mind, because they are more or less repeated in the length curves of the leaf-sheath and lamina, and emphasize the fact that the organs in varieties of the Saretha series are longer than those in the Sunnabile group, and that the maximum development takes place earlier in the former group in all cases. The Saretha cane develops more rapidly in all its parts.

We have now at our disposal the data on which to build the ideal cane for each group, in that we know the relative length of joint in each, as well as the variations in thickness at different points, and to complete the picture a reference may be made to a preceding paragraph where the thickness of the canes in different regions is discussed. In preparing such a scheme for an ideal cane, it must of course be borne in mind that these particular curves refer only to canes of the two groups grown in the Cane-breeding Station. The growth of canes of any one variety varies considerably with climate and soil, as has been abundantly demonstrated by measurements taken at various places in North and South India. But the main differences between the two groups, shown by the measurements and curves, appear to hold good wherever the canes are grown under identical conditions.

Colour of Cane.

Observations on the colour of canes are extremely difficult, and the results are often confusing. This is not only due to the fact that the colour of a joint varies constantly with its age, but also that it is affected by the presence or absence of bloom (which is often partially rubbed off), and the blushing of parts which have become accidentally uncovered by the leaf-sheaths and exposed to the sun and weather. Furthermore, the colour of some canes is known to change considerably after being cut, while it does not in others, and the same applies to canes taken from one locality to another, where some assume a totally different tone in the new conditions. The present summary is based upon a series of observations at different stages of growth in the canes harvested in 1916 and 1917 in the Cane-breeding Station, checked to a large extent by notes on their colour in the localities from which they have been collected. The views of different observers have been collated, and these latter included general, bulk observations made in the field and detailed analyses, joint by joint, in the laboratory.

One of the first results of this study has been the discovery of a distinct cleavage, in the Saretha group, into those which develop brown markings on the stem and those that do not. The former include most of the thin, primitive

canes of the Punjab and neighbouring parts of the United Provinces, whereas the latter consist chiefly of the thicker canes of Bihar, Assam, and the Peninsula. But, just as, in the Saretha and Sunnabile groups, prototypes were met with in *Katha* and *Dhaulu* of the Punjab, so here, a primitive, green cane of the Saretha group is met with growing with these, namely, *Mesangan*.

The brown canes of the Saretha series, which may be termed the Katha section, are as follows, in the order of thickness:—*Rakhra*, *Katha*, *Ramui*, *Lalri*, *Chin*, *Chunnee*, *Baraukha*, *Kansar*, *Chynia*, *Burra Chunnee*, *Saretha*. Those of the Mesangan section are *Mesangan*, *Saretha* (often called *Dhaur Saretha*), *Jaganathia*, *Khari*, *Hullu Kabbu*, *Ganda Cheni*, *Kalkya*. With the exception of *Mesangan*, the whole of its group are almost as thick or thicker than the thickest of the Katha section. This division of the Saretha group into two sections appears to be a real one, for, although united in most characters and opposed to the Sunnabile group in these, they differ in a number of characters, in that the Mesangan section often tends to occupy an intermediate position between the Katha section and the Sunnabile group.

In the following description of colour in the stem, it will be found convenient to consider the growth ring and the root zone separately. The rest of the joint will be studied, in succession, as to its general tone of colour, striping, black incrustations (cell outgrowths), bloom, blackening (fungus on bloom), and corky markings. The two sections of the Saretha group will, as far as possible, be taken together, differences between them being pointed out where they have been observed.

(1) *General colour*. Saretha group. Colour much obscured in the lower parts by weathered bloom, and usually dirty there. Brown, bone yellow, green or grey, occasionally light purple (brown, covered by bloom) at the base, passing upwards to yellow, glaucous green, green yellow or grey, and finally to greyish or glaucous or whitish green or even white at the top owing to excessive bloom. In the Mesangan section the browns are absent or extremely rare and, consequently, the joints are rarely light purple. The brown occurs as patches, or streaks or a general tone, and increases with age. It is therefore more marked in the lower parts of the mature cane.

Sunnabile group. Brownish stone-coloured or glaucous yellow, occasionally green, below, passing upwards to clear light stone or greenish yellow, with distinct green patches at places where the cane is bent; finally, to clear stone yellow, occasionally greenish yellow or dull green, at the top. *Putli Khajee* is a vivid grass green cane and *Ketari* has a general greenish tinge, when compared with the rest.

(2) *Striping.* The observations on this point must be considered incomplete, for, with only 10 to 20 canes examined, it is quite possible that the character may have escaped notice, and may be only very occasionally present. Striping has not been met with in any of the Katha section of the Saretha group, four out of seven of the Mesangan section have shown it, while it has been noted, usually with great ease, in fourteen out of fifteen of the Sunnabile group, *Dhaulu* alone appearing to be without it (in the observations recorded). This striping is extremely faint and consists of fine purple lines on the lower parts of the canes.

(3) *Black incrustations.* This is a marked character in all the varieties of the Saretha group and is totally absent in the Sunnabile series. It is therefore a prime character. Its nature has long been a puzzle, but a series of sections have demonstrated that it is caused by the enlargement and protrusion of certain epidermal cells whose contents assume a brown and ultimately charcoal black colour. It is an obvious roughness on the surface and hence has the appearance of an incrustation, and was at first thought to be caused by the bites of minute insects or mites; but no exuviæ of any kind have been found. It occurs typically in the groove -which is absent in the Sunnabile group- -but may extend to all parts of the joint, and sometimes occurs in such masses that it gives a characteristic colouring to the whole cane, especially in its upper part. It is worth while recording that a similar black or brown incrustation is very commonly met with on the stems of *Saccharum spontaneum*, including the Dacca water form.

(4) *Bloom.* The waxy layer of the epidermis appears as thick layers of bloom in the Saretha class, especially in upper parts of the canes. It is sometimes difficult to make out the limits of the bloom band, because of the extent to which this layer of bloom descends over the joint, and it is not uncommon for the whole upper part of the cane to become grey or even white because of it. The Katha section has more bloom than the Mesangan and this adds to the differences of the two sections in colour. The bloom bands, excepting in the case noted above, are rather distinct in the group, but become obscured by weathering in the lower parts of the cane. In the Sunnabile group the bloom is not heavy and it descends over the cane surface to a much less degree. The bloom bands are not usually so conspicuous, but this is partly due to the yellow colour of the canes: in *Putli Khajee*, a bright green cane, the bands stand out very distinctly. The quantity of bloom on the canes of the two groups varies very consistently and this character is therefore one of some importance.

(5) *Blackening* is induced by the growth of a minute fungus upon the bloom or waxy layer of the outer walls of the epidermis, and is present in all canes. Although variations in blackening have not at present been studied in different localities and climates, it would be natural to suppose that, where there are thicker masses of wax on the stem, the blackening would be more widely spread and denser. This, however, does not appear to be the case, although there is a considerable difference in its occurrence in the Sunnabile and Saretha groups. In the varieties of the latter, with large quantities of bloom, blackening is fairly common, but it is rather faint and diffused, as if the cane surface had been lightly smudged with soot. On the other hand, in almost all of the Sunnabile group the blackening, whether abundant or comparatively scarce, is intense and sharply circumscribed, contrasting markedly with the bright yellow stems. Blackening of the stem is thus a character of some use in separating the two groups.

(6) *Corky markings.* These are, as already intimated, essentially splits in the epidermal layers, although it usually requires a lens to determine this fact. They were called " ivory markings " in Memoir 1, but the present term appears to be more suitable. It appears possible that the locality in which a cane is grown may have considerable influence on their development, in that canes, which were noted as having very few corky markings in their native habitat, have developed them copiously at Coimbatore and *vice versâ.* Corky markings cannot therefore usually be considered a character of much importance in classification. When we remember, however, the black incrustations which are so uniformly present in the Saretha series and as constantly absent in the Sunnabile varieties, it is worth while examining the corky markings of the two groups more carefully, as in each case we have to do with the epidermal layer of the cane stem. A careful study of the corky markings, in the different varieties comprised in the two groups, has convinced me that there *is* a difference in their mode of development, although this is not easy to express. For one thing, these markings are, with few exceptions, much more abundant and striking in the members of the Sunnabile group. And there seems to be a difference in their mode of development, as will be seen from the following. There appear to be three different modes of occurrence in the cane varieties under discussion.

(*a*) Long, thick, parallel lines, rather widely separated and extending from the base of the bloom band about two-thirds down the length of the joint. This form is practically universal in the Sunnabile series although not noted in the Saretha varieties. It not infrequently happens that, in a cane with

comparatively few corky markings, a joint is met with high up, which is simply crowded with them, but the meaning of this is not apparent.

(*b*) Short, fine, wavy, closely packed markings, occurring hereand there over the joint, and those at the top sometimes passing into the bloom band. This form is more frequently met in the Saretha series, although it also occurs between the strong parallel lines in some Sunnabile varieties.

(*c*) Short, irregular splits, obvious to the naked eye as such, which appear as cracks through the bloom band. These cracks are unlike the corky markings mentioned above, but are presumably of the same nature, in that the other forms sometimes pass into them. They are present in many varieties of both series. *Hotte Cheni* has been singled out as a form in which all of these forms of corky markings are abundant.

(7) *The colour of the growth rings and root zones*, like the bloom band, sometimes adds considerably to the general effect of the cane colour. Thus the strong white bloom bands, contrasting with the brilliant green of *Putli Khajee*, give it a very striking appearance. In the same way the effect of the colour in the growth rings and root zones depends on the general tone of the cane, and the bright green colour of these bands in *Putli Khajee* makes it difficult to distinguish them. The colour of the growth rings depends a good deal on exposure, the general tendency being for them to assume a darker colour in exposed joints. This is especially noticeable in the brown canes of the Katha section of the Saretha series, where the colour is usually strongest at the upper and lower margin of the ring. This dense browning of the growth rings adds considerably to the general brown effect of the cane colour. The colour at this part of the joint is usually rather lighter in the green canes of the Mesangan section. but the contrast with the glaucous green or glaucous yellow of the rest of the joint often renders them distinct. In the Sunnabile group, on the other hand, the growth rings are distinctly fainter, being often rather brownish yellow than brown. They are usually most clearly seen in the middle of the cane, where they contrast sharply with the clear stone yellow, but they are obscured below by their similarity to the general cane colour. In the younger parts, the growth rings assume a greener tinge. This is especially the case in the canes of the Katha series, where they are often narrow and distinctly depressed. They are green or brown green in the young joints of the Mesangan section and often more brown than green in the Sunnabile group, where also the depressed character is less evident. The root zones are not usually very conspicuous, often taking on the colour tone of the rest of the cane. They are, however, generally paler or yellower. They may be

described as brownish cream below, gradually becoming a lighter cream colour and often bloomed in the young joints at the top. The root zones of the Sunnabile group appear generally to blush a bright green on exposure, and are then very striking, as the eyes remain a clear yellow. There are traces of this green blushing in the Mesangan section of the Saretha group, but it appears to be absent in the brown canes of the Katha section.

JOINT CHARACTERS.

The characters of the joint have been largely included in the preceding description of the cane as a whole. Such are the number of joints in the cane, their average thickness and length and the thickness and length in different parts, the colour of the joint, including bloom band, root zone and growth ring. A great deal of time has been spent in observations in the shape of the joint and descriptions have been recorded from time to time on the aspect of the joint both in the median and lateral planes. But, although it is felt that there are differences, these are not very striking or easy to put down clearly. For one thing, the shape of the joint varies a good deal with its length, differences in diameter at various points being emphasized in shorter joints, and this introduces a further disturbing element in the analyses. There are, however, a few other points, not yet dealt with, in which joint differences have been noted in the varieties of the Sunnabile and Saretha groups.

(1) *Groove.* The presence or absence of a groove or depression immediately above the bud, often considered of minor moment, turns out to be a character of first importance in our comparison. The groove is always present or indicated in the Saretha group, while it has at present never been met with in any variety of the Sunnabile group. The groove varies, it is true, a great deal in its development, sometimes extending distinctly from the bud to the bloom band above, and at others merely indicated by a flattening of the surface or a small depression above the bud, the rest of the joint being evenly rounded. It is worth while drawing attention again to the black incrustations already described, as there seems to be a distinct connection between these and the groove, and both are characteristic of Saretha canes.

(2) *Circlet of hairs.* The vestiture of the leaf scar appears to offer useful distinguishing characters. This might have been expected, because we have elsewhere been led to consider the circlet of hairs, with its attendant scar band of felt, as suggesting a primitive relationship. This circlet of hairs is well developed in and characteristic of all the members of the Saretha series. There is some evidence that its development varies to some extent with climatic

conditions, for in 1916 it was poorly shown, but in the same canes it was well developed in earlier years, both on the Cane-breeding Station and in their native habitat in the north. In the Sunnabile group, on the other hand, the circlet of hairs is altogether absent or present only in the lower joints, and then rapidly disappears upwards, although this is not so pronounced in *Rakhra* and *Kaghze*.

(3) *Scar band and scar line.* Below the circlet of hairs and passing into it from the bloom band is the scar band. The latter consists of a band of close pubescence, of a dull dark or grey, sometimes greyish green, colour, while the scar line in the same position is, typically, a sharp, smooth, hairless, dark brown line. In some cases it is difficult to distinguish between the scar band and scar line, as the latter may be broad and ill-defined and the former may be rather sharp and narrow. But, taking the varieties as a whole, the Saretha group is characterized by the presence of a scar band while the Sunnabile varieties, as distinctly, show a scar line. This scar line in the latter series, on the other hand, is not nearly so distinctive a character as the sharp, dark brown line of the Mungo group. It is often broad and rather ill-defined, so that it is sometimes difficult to separate it from a band in certain parts.

We have now met with three characters which point to the Saretha group comprising more primitive varieties with distinct connecting links with *Saccharum spontaneum*, for the circlet of hairs is often abundantly developed in the latter. The dissection of the stools, black incrustations and circlet of hairs all show such a relationship, and in each of these particulars the Sunnabile series is sharply marked off from the Saretha group.

(4) *Growth ring.* These are usually definite, at the upper and lower margins, in both series, although, in certain of the Saretha series, the upper margin is wavy and there is a tendency for the dark colour of the growth ring to invade the joint above and root zone below. This definiteness it may be remembered is absent in many of the Mungo group and in many thick canes.[1] The growth rings are usually not wide excepting at bends. From a series of measurements in the laboratory, it appears that the width of the growth ring bears no relation to the size and thickness of the cane. The averages of the measurements of breadth are as follow in 10 canes of each variety (top, middle and bottom being separately measured) :—

Saretha group	Brown section	0·11″
Do	Green section	0·14″
Sunnabile group	.. .. ..	0·08″

[1] Mem. 1, p 23.

Thus the Sunnabile group has considerably narrower growth rings. It is possible that this may have some relation to the fact the Sunnabile canes are straighter, thicker, shorter and less liable to bending, for the growth ring consists of meristematic tissue which comes into activity and broadens where any bend occurs.

(5) *Root zone.* Measurements of the width of root zones lead to a different result. The thinner canes, generally, have narrower root zones than the thicker. The following are the averages of measurements taken at the same time as and similarly to those of the growth ring.

Saretha group	Brown section	0·22″
Do.	Green section	0·25″
Sunnabile group		0·34″

The root zones of the Sunnabile group are thus considerably wider than in both of the Saretha sections. This is more striking in that the growth rings are narrower in the Sunnabile series, and the relative width of growth ring and root zone in the two groups is very different. The root zone is almost half as wide as the growth ring in the Saretha group but less than a quarter as wide in the Sunnabile group.

The shape of the root zone, when viewed from the side, appears also to differ, but it is not easy to put this down clearly. In Saretha the root zone is usually slightly swollen in the lower part of the cane, then becomes straight-sided and then, towards the apex, it often narrows downwards. In the Sunnabile series it is not usually swollen below and quickly passes to the condition of narrowing downwards. Of course, swelling below is dependent upon the stage of development of the adventitious roots, but the canes examined were all resting in this respect.

The root eyes seem to differ rather more in the two groups. They are usually very difficult to make out in the joints of Saretha varieties and are disposed in two or three equidistant and more or less similar rows. In Sunnabile they are usually more distinctly visible, are rather more abundant (2 4 rows) and are characterized by the lower row being distinctly separable from the rest. The eyes are much larger in the lowest row, and there is often a considerable space between it and the rest, which are congested in the upper portion of the root zone. In *Putli Khajee* the eyes are especially numerous, those of the lower rows are large and corky and run into one another, while the upper rows are very irregular and consist of closely packed small eyes.

To sum up the differences observed, other than colour, in growth rings and root zones, Saretha has wider growth rings and narrower root zones and

the eyes in the latter are uniformly disposed in two or three rows. The growth rings are narrower in the Sunnabile series and the root zones are wider, and often contain more rows of root eyes, the lowest of which is separable from the rest and has eyes of a considerably larger size.

BUD CHARACTERS.

In comparing varieties of sugarcane, one always turns to the bud, as an organ in which it is safe to find differences in one form or another. The buds have therefore been subjected to a careful scrutiny in all the varieties under consideration. In both classes they are distinctly small, often not exceeding the growth ring in length and, consequently, such differences as exist must be packed up into small compass. Furthermore, on separating the Katha (brown) from the Mesangan (green) sections of the Saretha group, the latter is found to be transitional between the Katha section and the Sunnabile series, and this introduces complications which were not understood until the two Saretha sections had been separated. In the nature of things, the study of such small buds has tended to become microscopic, and such differences as have been noted are likely to be less useful in separating the two classes in the field. The comparatively dry climate in which the canes are grown at Coimbatore does not admit of much shooting of the buds, and this character is generally absent, excepting at the tops of canes which have flowered; and, as we have seen, the Saretha group flower much more freely and regularly than the Sunnabile series. This shyness of shooting is, however, of great advantage for our general study, in that the buds, although mature, are resting.

(1) *Bursting.* In the Saretha group, the bursting of the buds is generally apical, as indicated by the convergence of the veins of the lowest bud scale. Occasionally buds show dorsal or more frequently high dorsal bursting, but these are usually low down on the cane and are practically confined to the Mesangan section. In the Sunnabile group the bursting of the buds is dorsal, with occasional exceptions in the upper part of the cane.

(2) *Size.* All the varieties, excepting *Mojorah*, have small buds. They are smallest in the thin canes of the Katha section, while the thicker members of the Mesangan section and the Sunnabile group have practically equal sized buds. The average variations in length are as follows :—Katha section 0·17″—0·3″, Mesangan section 0·22″—0·32″, Sunnabile group 0·22″—0·32″, from which average lengths of 0·23″, 0·27″, 0·27″ may be deduced. This seems to indicate a close relationship between thickness of cane and length of bud, but a study of the individual varieties shows a fair number of exceptions, and it cannot be

taken as a general rule. The relation between the width of root zone and the length of bud is, however, more instructive. The following are the proportional figures—root zone to bud :—Katha section 0·22″ : 0·23″, Mesangan section 0·25″ : 0·27″, Sunnabile group 0·34″ : 0·27″. In the latter group the buds appear to be shorter than in the Saretha series as a whole and this appearance is explained by their frequent failure to reach the growth ring in the lower parts of the cane. The bud in the Sunnabile group is also lengthened by the addition of the flanges, which often form a broad ring round the apex, which is not the case in the Saretha series. In the Saretha group, the buds usually reach the growth ring in the lower part of the cane and exceed it in the upper. In the Sunnabile series the bud often fails to reach the growth ring below, and comparatively rarely exceeds it above.

(3) *Form.* In form the buds of the different members of the two groups vary a good deal. On the whole those in the Saretha group are more pointed and may often be described as ovate, whereas (partly because of the border flanges) in the Sunnabile series they are more oval. In both groups the buds are occasionally truncate and in the Sunnabile varieties sometimes even emarginate at the apex.

(4) *Colour marks.* The buds in both series are frequently marked by dark brown colorations. These marks are found more frequently at the base and along the edges of the scale in the Saretha group, whereas in the Sunnabile varieties it is the flange surface which is usually browned and this causes the colour marks to converge upwards like the head of an arrow.

(5) *Place of origin.* All the buds arise at the leaf scar, at any rate in the lower part of the cane, and there is no trace of cushion. There is, however, a steady tendency in the Sunnabile series for the upper buds to arise a little above the scar. The Mesangan section is transitional in this character to the Katha section, where this higher origin of the bud has not been observed. It will be remembered that the high origin of the buds and the appearance of a cushion are characteristic of the Pansahi group of canes.

(6) *Flanges.* There are marked differences between the two groups in the flanges of the lowest scale of the bud. In the Saretha group they are usually narrow, their outline is not readily traced and is often obscured by bristles. In the Sunnabile group they are, on the other hand, well seen, being fairly broad and often free of bristles, and forming a broad border round the apex of the bud.

(7) *Bristles.* Bristles are fairly well developed and sometimes abundant in the Saretha group but are sparse, irregular or almost absent in most of the Sunnabile series

(8) *Basal patches*. These are well and typically formed in most of the Saretha series, often consisting of closely parallel, curled or crisped patches of shining white hairs, on each side of the lower part of the bud. They are, with few exceptions, poorly developed in the Sunnabile series, where they are often indicated by a pubescence or roughness in which it is difficult to make out individual hairs. In one or two varieties, however, they are well developed and conspicuous, as in *Putli Khajee* and, to a less extent, in *Bansi*.

(9) *Minute black hairs*. These were first observed when comparing *Katha* with *Dhaulu* of Gurdaspur. Their presence or absence is found to be a general character for the two groups of which these varieties are the prototypes. They are practically absent in the Katha section, generally present in small numbers in the Mesangan group, and usually abundant in all parts of the bud in the Sunnabile series.

The study of the buds in the Saretha and Sunnabile varieties has led us into a series of minute and apparently unimportant characters. It should here be emphasized that the bud is practically an epitome of the vegetative shoot of the cane, and there is little doubt that the descriptions given err, not on the side of the minuteness, but in being less microscopic than they ought to have been. The excuse for this is that there has not been sufficient time to carry the observations further, and that, perhaps, the more general descriptions recorded above will serve the purpose of this paper. We have seen in each character examined that differences have been recorded, whether in bursting, size, colour marks, origin, flanges, or hairs on the bud, and this has justified the large amount of time spent on this part of the cane plant.

Leaf Sheath.

The leaves of the sugarcane offer a perfect mine of characters whereby the different varieties may be distinguished, and there is little doubt that many more would reward a patient study in other directions. There is evidence that microscopic features such as the siliceous protrusions from the epidermal cells, the numbers and arrangement of the stomata, and so forth, would offer differences and, doubtless, a study of the anatomy of the leaves would add to these. The characters dealt with here are macroscopic and hardly require the use of a low-powered hand lens. With the exception of the detailed measurements given later, most of them can be readily observed in the field. The leaf sheath is treated separately from the lamina and the ligule and ligular processes are included in it. The following are its more obvious characters.

(1) *Colour*. This is complicated by the fact that a large portion of the leaf sheath in the growing shoot is covered by those lower down on the stem.

The colour of this covered portion is usually yellow or green or a mixture of the two. Bloom is usually absent in this covered portion. When the leaf sheath is exposed, it assumes some form of green colour, this depending largely on the quantity of bloom present. Differences occur in the varieties of each group, and it has not been found possible to introduce uniformity in the groups. In the Katha section the colour of the exposed leaf sheath is a dark bluish green, turning greyish green where there is bloom. In the Mesangan section the colour is grey green to full green, while in the Sunnabile group there is a good deal of variation but the greens are often light in tone.

(2) *Bloom.* A similar lack of uniformity in the members of each group is met with in the quantity of bloom on the leaf sheath. Katha and Mesangan sections show hardly any bloom, and, in the former especially, the exposed part of the sheath is frequently shiny. Bloom is slightly more developed in the members of the Sunnabile group and there is a good deal in *Bansi.* Small patches of bloom are not infrequently present on what are called below "transverse bars," where small swollen cross veins pass from one longitud nal vein to the next, and the bloom patches are sometimes the only indication of their presence.

(3) *Scarious border.* When the leaf sheath becomes old, its edges turn a light brown or straw colour. This sometimes takes place very early in the life of the sheath, and shows up clearly against the general green colour. I have termed it the *scarious border.* It is especially present in all the members of the Sunnabile group, where even the youngest leaf sheaths exposed already show signs of withering at the edges. In the Katha section the scarious border is absent in the young shoot, while in the Mesangan section it shows signs, here and there, of commencing early but to nothing like the extent in the Sunnabile series.

(4) *Colour of young edges.* Besides the scarious border, there is another respect in which the edge of the leaf sheath exhibits distinguishing characters. It is quite possible that the two colorations are connected, but they are distinct phenomena and are frequently present at the same time in a sheath. The edge of the young leaf sheath has a different tone of colour to the rest. In the Katha section it is light coloured, sometimes white, and often transparent. It is also light coloured in the Mesangan section. In the Sunnabile group, on the other hand, the young edge is often of a red brown colour as far up as it can be seen, while this colour always makes its appearance very early. It is sharply marked off from the adjoining green, and is frequently limited outwards by a white border.

(5) *Tuft of hairs.* This is met with, in varying degree, in all canes. It arises in the two upper angles of the leaf sheath where it merges into the lamina, and not infrequently extends downwards on the edge of the sheath and upwards along the lamina. It is sometimes very conspicuous and silky white. This tuft of hairs is not very greatly developed in either group. It is small in the Katha section and is not usually decurrent along the edge of the sheath. It is meagre in the Mesangan section, slightly descending or not, but descends freely in *Hullu*. In the Sunnabile group the tuft of hairs is small to moderate, it is usually decurrent and sometimes very freely so.

(6) *Spines on the back.* Siliceous hairs, frequently adpressed and always directed upwards, are a marked feature of the leaf sheath in many varieties of cultivated and wild Saccharums, and, indeed, are sometimes a factor to be reckoned with in harvesting the canes. They appear to be totally absent in both sections of the Saretha group, but are characteristic of members of the Sunnabile series. One of the two specimens of *Khadya*, however, received from Bombay, appears to be glabrous. The spines are usually concentrated in a small, dense group in the middle of the back of the sheath, rather high up, but have been occasionally recorded near the upper part of the two edges. Occasionally they are not visible, but can be quickly detected by passing the hand gently down the sheath.

(7) *Venation.* This is often well marked in the leaf sheath, and consists, typically, of fine, parallel lines extending down its whole length. They are particularly well seen in the covered part of the sheath, forming dull lines on the yellow background. In the uncovered portion, they are especially well seen in the Katha section, where they are clear and rather fine and numerous. They are moderately distinct in the Mesangan section, but are irregular, often thickish, and indistinct in the Sunnabile series.

(8) *Transverse bars.* These, as stated above, are also veins, forming cross connections between the longitudinal ones, chiefly in the upper part of the leaf sheath. They are typically present in *Saccharum spontaneum* and seedlings obtained by crossing it with cultivated canes. They are often thick and swollen and present the appearance of having been flattened by the pressure of the leaf sheath. Varieties in the Katha section usually have them well developed, although they are not always very distinct, and sometimes only represented by strong patches of bloom. The transverse bars are less marked in the Mesangan section and are usually absent in Sunnabile varieties or merely indicated by small splashes of darker green.

It is perhaps worth while drawing attention here to the continued resemblances between the Katha section of the Saretha group and the wild *Saccharum spontaneum*, and also to the transitional position so often seen of the Mesangan section between the Katha and Sunnabile varieties. This would suggest a line of evolution along which the cultivated sugarcane has been selected, having its origin in a primitive form somewhat similar to a Katha variety, and passing through some such form as a Sunnabile variety, already differentiated to a certain extent and in some respects approaching the higher forms of cultivated canes.

(9) *Ligular processes.* These are upward scarious extensions of the edges of the leaf sheath on either side of the base of the lamina, provided with a rudimentary fibrovascular system, and are usually most prominent on the inner margin of the sheath. They are clearly connected with the ligule which passes into them at its edges and this suggests that the ligule is morphologically an overlapping portion of the leaf sheath at its point of junction with the lamina. The Katha varieties usually have well developed ligular processes. They occur as long, sharp teeth, usually reaching an inch in length and occasionally extending to double that length, when they form a striking and characteristic feature. They are not usually present in the Mesangan section, although *Ganda Cheni* has been noted as having occasional ligular processes up to half an inch in length. In the Sunnabile group they are reduced to the usual blunt angle, which soon becomes scarious, owing to the notching in the margin where the sheath and lamina unite.

(10) *Ligule.* This is treated here because of the possibility indicated above of its being part of the leaf sheath, and its intimate relation to the ligular processes. It is narrow in both groups, although varying a little in this respect in the Mesangan section and the Sunnabile group. In the Katha section the ligule is usually flat or slightly depressed in the middle of its upper margin and deeply depressed on its lower. In the middle it is distinctly broader than at the edges and there is often a small triangular or diamond-shaped portion here which is termed a *lozenge*, but this is not always present. The ligule in the Mesangan section is flat or arched above and deeply depressed below. There is usually a lozenge, although this is sometimes absent. The typical ligule of Sunnabile varieties is arched above, often with a flat depression in the middle and slightly depressed below. The two margins are often nearly parallel and the lozenge is thus absent.

The setæ on the upper margin of the ligule present more striking differences, as is often the case with hairs and hair-like structures. They are extremely

small in the Saretha group, irregular, sparse and not infrequently deciduous or absent in the Katha section, but occasionally more abundant in the Mesangan varieties. In the Sunnabile group they are strongly developed and are usually long, and there are often a few scattered, very long setæ, standing out in the middle of the ligule.

(11) *Clasping stem at base.* In the varieties in the Saretha group the leaf sheath at its base clasps the stem more widely, although the differences are not great. This is in accordance with observations made when comparing *Katha* and *Dhaulu of Gurdaspur.* The extent of encirclement is expressed in terms of the circumference of the stem, thus, 1·00 would indicate that the leaf sheath just encircles the stem once and 1·50 would show that it goes one and a half times round. The figures obtained for 8 Saretha and 10 Sunnabile varieties measured in 1916 are 1·45 and 1·35 respectively—roughly the sheath passes one and a half times round in Saretha and one and one third in Sunnabile. In the larger series examined in 1917 the difference is reduced, although it is in the same direction. The figures are 1·46 for Saretha and 1·39 for Sunnabile groups. The Katha section clasps the stem most widely, 1·48 being its figure: the Mesangan section gives the figure 1·43 and the Sunnabile group 1·39.

(12) *Width at base.* The Sunnabile varieties, in spite of less encirclement of the stem by the base of the sheath, have wider sheath bases, and here too the Mesangan section is intermediate between the Katha section and the Sunnabile group. The average widths of the base of the leaf sheath are, for 1916, Saretha group 3·09″, Sunnabile group 3·37″; for 1917, Katha section 2·79″, Mesangan section 3·16″ and Sunnabile group 3·26.″

(13) *Width at apex.* Here too, the sheaths are wider in the Sunnabile group, falling into line with a greater thickeness of stem and greater width of leaves. The 1916 measurements show averages of 1·23″ for Saretha and 1·34″ for Sunnabile groups: in 1917 the figures being 1·22″ and 1·30″ respectively. But a variation is to be noted in the Mesangan section, which is not in this case at all intermediate between the Katha section and the Sunnabile group. The width at the apex of Mesangan section averages 1·40″, that of Katha section 1·11″, while the Sunnabile group is intermediate with 1·30″.

(14) *Length of mature leaf sheath.* The length of leaf sheath appears to differ less definitely in the Saretha and Sunnabile groups than that of joint and lamina. In fact, while it is distinctly longer in Saretha in the 1916 measurements of mature canes, little difference has been noted in those of 1917. This may be due to the fact that the maxima are rather late and that, in the immature canes of the latter crop, the full length of the leaf sheaths had not

been obtained, but this interpretation is open to doubt. The results of the measurements are as follow:—1916, based on averages of 20 canes of each variety, Saretha 12·4″, Sunnabile 11·6″: 1917, measurements of 20 canes, Saretha 11·9″, Sunnabile 11·9″: measurements of 10 canes in the laboratory, Saretha 11·95″, Sunnabile 12·02″. The agreement of the two 1917 measurements is very close.

(15) *Module.* This empirical expression is obtained by dividing the average length by the greatest width, that at the base. It is designed to give some idea of the shape of the leaf sheath and is included because it has been found so useful in the cane and the lamina. We have seen that the sheath is wider at the base in the Sunnabile group, while the length of the sheath, longer in the 1916 results in Saretha, is practically the same in the two groups in 1917 measurements. It is not surprising that the Sunnabile sheath has a lower sheath module. Also that this module is higher in the Mesangan section than in the Sunnabile group. The figures are, for 1916, Saretha group 4·0; Sunnabile 3·5; for 1917, Saretha 4·1, Sunnabile 3·7 figures which show sufficient agreement. The figures in the Katha and Mesangan sections of the Saretha group, in 1917, are 3·8 and 4·4 respectively.

(16) *Number of sheaths per cane.* The sheaths are, as might be expected, more numerous in the Sunnabile group, although there is little difference in the poorer grown 1917 crop. The figures were, in 1916, Saretha 35 Sunnabile 45; in 1917, Saretha 29, Sunnabile 30, the figures for the Katha and Mesangan sections being 30 and 28 respectively.

(17) *The variations in sheath length in different parts of the cane.* As in the length of joint, the length of sheath was measured by foot rule divided into tenths of an inch, in 20 canes of each variety, both in 1916 and 1917. In 1916, 7 varieties of the Saretha group and 10 of the Sunnabile were measured, and the canes were over-ripe. In 1917, the number of varieties were 18 and 15 respectively, but some of these have been ruled out, in that it was not possible to obtain fair averages because of the large number of missing sheaths. It is natural that differences would be lessened in the latter case and, perhaps, more reliance is to be placed on the 1916 results. The following are the averages obtained in the 1916 measurements, the lengths of sheaths being recorded, from base to apex, in inches.

1916. Saretha group. 12·2, 12·6, 12·9, 13·0, 13·2, 13·3, 13·2, 13·2, 13·1, 12·9, 12·7, 12·6, 12·5, 12·4, 12·3, 12·3, 12·2, 12·2, 12·3, 12·3, 12·0, 11·9, 11·8, 11·6, 11·5, 11·4, 11·2, 11·0, 10·8, 10·1, 8·8, 5·2, 1·3, 0·3, 0·1.

Sunnabile group. 11·1, 11·3, 11·5, 11·5, 11·7, 11·6, 11·7, 11·8, 11·9
11·8, 11·8, 11·8, 11·8, 11·7, 11·6, 11·8, 11·9, 12·0,
12·1, 12·1, 12·0, 12·0, 11·9, 11·9, 11·8, 11·7, 11·7
11·5, 11·3, 11·3, 11·3, 11·1, 10·9, 10·7, 10·8, 10·9,
10·7, 10·3, 9·6, 7·7, 3·3, 0·8, 0·2, 0·1.

These figures plotted out on curves, show some interesting characters (Chart III).

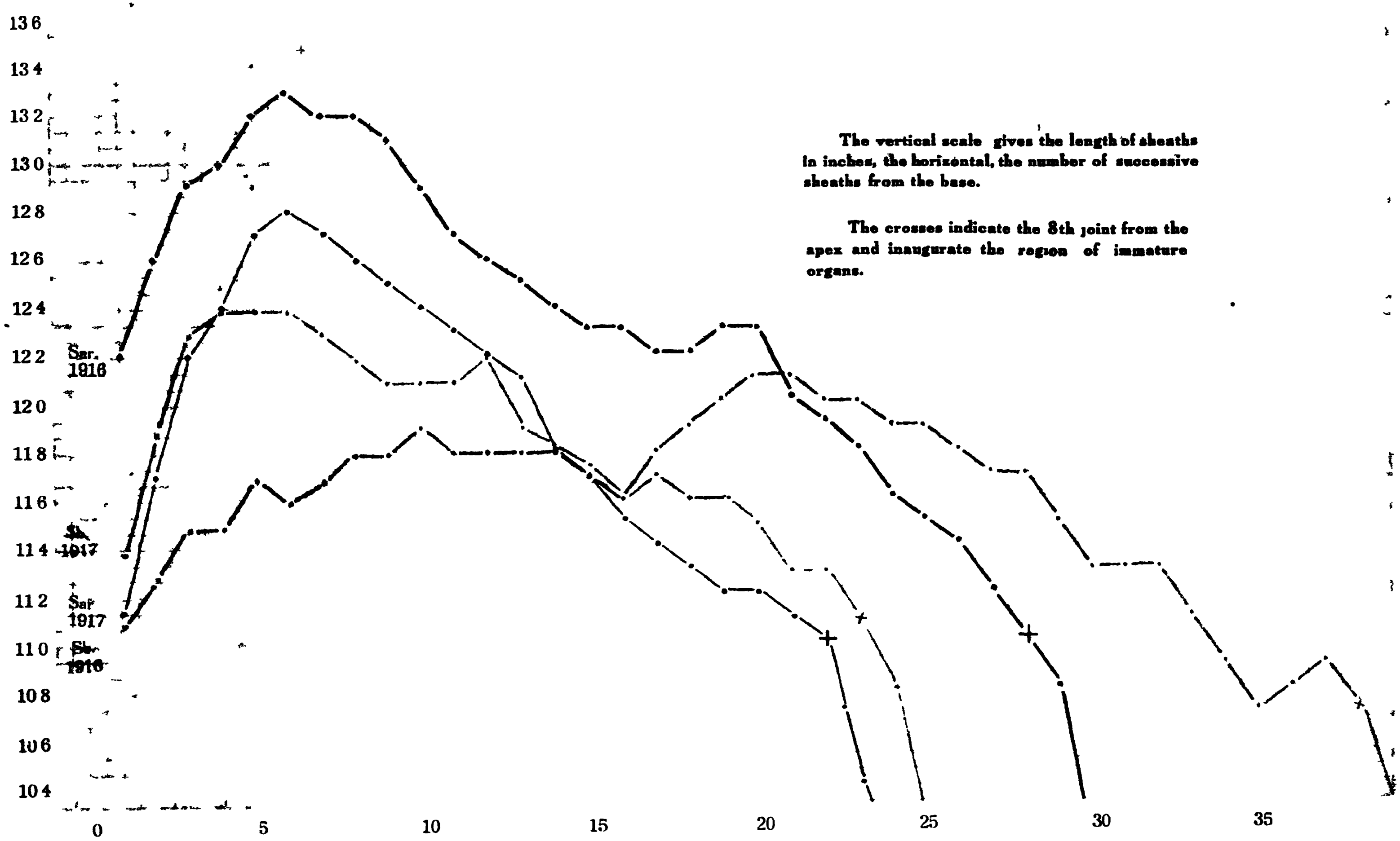
(18) *Curves.* In the Saretha group, in 1916, the curve commences high, ascends steeply to an early maximum, then descends steadily with a slight indication of a second maximum half way down, and the curve leaves the paper considerably sooner than that of the Sunnabile group. The curve of the latter commences low, rises gradually to a first maximum and attains its highest point very late. It crosses the Saretha curve about half way along its course and then descends steadily but less steeply than in Saretha and shows an indication of a final small maximum before it leaves the paper. The crosses mark the position of the eighth sheath from the end, and those beyond may, for convenience, be considered all immature and need not concern us. The curve in Sunnabile is much longer, the number of sheaths before the last eight being 37 as against the 27 in Saretha. Comparing the two curves, that of Sunnabile is longer, lower, flatter, characters which we noted in the curves of the lengths of joint in the identical sets of canes. In fact, there is considerable similarity between leaf sheath and joint length curves in any cane although this resemblance is not close enough to establish a definite correlation between joint and leaf sheath.

The 1917 measurements were taken in a much larger number of varieties in each group and the canes were measured when only nine months old, to ensure the presence of sheaths and leaves in good condition. But, unfortunately, the growth was poor in most of the varieties and especially so in one or two—being nothing like so good as in the previous year. The number of joints and consequently of leaf sheaths were much below the average and, generally, normal differences were much reduced. The following are the figures obtained in 1917 for lengths of successive leaf sheaths.

Saretha group; averages of 18 varieties with 20 canes in each variety in inches:

11·1, 11·7, 12·2, 12·4, 12·7, 12·8, 12·7, 12·6, 12·5, 12·4, 12·3, 12·2, 12·1, 11·8, 11·7, 11·5, 11·4, 11·3, 11·2, 11·2, 11·1, 11·0, 10·4, 9·7, 8·5, 5·1, 1·3, 0·2, 0·1.

CURVES SHOWING THE AVERAGE LENGTHS OF SUCCESSIVE LEAF SHEATHS FROM BASE TO APEX, IN THE SARETHA AND SUNNABILE GROUPS IN THE 1916 AND 1917 CROPS.



Sunnabile group ; averages of 15 varieties :

11·4, 11·9, 12·3, 12·4, 12·4, 12·4, 12·3, 12·2, 12·1, 12·1, 12·1, 12·1, 11·9, 11·8, 11·7, 11·5, 11·7, 11·6, 11·6, 11·5, 11·3, 11·3, 11·1, 10·8, 9·7, 6·2, 2·1, 0·6, 0·2, 0·1.

Upon comparing the curves plotted from these figures, the first matter for notice is their extreme shortness, the Sunnabile excess number being reduced to one sheath, as was the case in the joints. The Sunnabile curve is, it is true, lower, flatter, longer, as was the case with the 1916 curves, it reaches a lower maximum than the Saretha and crosses it about half way along its course ; but there is far more resemblance between the curves of the two groups in 1917. In one particular is this especially noticeable. The three lowest sheaths are actually longer in the Sunnabile group, instead of being much shorter, and the initial rise in length is much steeper than was to be expected. This may be due to the conditions of growth, which may have affected the varieties of the two groups differently, but it is only fair to state that these initial sheaths were often absent or not susceptible of measurement, and the averages for the first few are accordingly much less reliable. Nevertheless the 1917 curve for the Sunnabile varieties is rather steeper than usual in this group and approximates in this respect to that of the Saretha group. Considering all things, more reliance is to be placed on the curves obtained in 1916, and the general differences noted in it hold, in a diminished degree, with those obtained in the immature canes of 1917. In the circumstances detailed above, I should feel inclined to build up the ideal cane rather from the 1916 curve, with the proviso that the differences between the length of leaf sheath in different parts of the canes in the two groups may be somewhat exaggerated in these curves.

Curves have been prepared for the Katha and Mesangan sections of the Saretha group. These show that the latter section, consisting of larger canes, only resembles the Sunnabile series in the number ot leaf sheaths. In other respects the curve approaches nearer to that of the 1916 measurements in the Saretha group, it is higher and steeper than that in the Katha section.

LAMINA.

The leaf blade or lamina has been subjected to a rather more exhaustive study than the leaf sheath, as it presents details of form which are absent in the latter. In no part of the plant is it more evident that a real difference exists in the two groups in the length and shape of organs, and the elaboration of this point has taken a good deal of time. For one thing, the differences between the

1916 and 1917 crops , so noticeable in the joint and leaf sheath, appear to have had less play in the lamina, and the similarity of the figures obtained in different observations is sometimes very striking. The persistence of differences in roughness, hairiness, venation, etc., would tempt one to make a series of observations with stomata, but this has not been accomplished, yet the surmise may be hazarded that one more useful distinguishing character may be expected from a study of these. The characters studied naturally divide themselves into those which are capable of measurement and those which are not. The latter, which are less complicated are taken first.

(1) *Channelling.* This infolding of the leaf at the base is a marked character of the Saretha group, in which it resembles the wild *Saccharum spontaneum.* The channelling is chiefly developed in the midrib but is not confined to it, and the lamina takes a more or less distinct part in all the varieties of the group. In the Sunnabile series the channelling is not usually so marked and it is confined to the midrib, while the lamina is flat to the base.

(2) *Callus.* This term is applied to the region of the lamina on each side of the midrib just above the ligule. It corresponds with the transverse marks of lighter colour on the back of the leaf. This part of the leaf differs a good deal in the two groups under discussion. The callus is not well marked in varieties of the Saretha series, it is usually covered by waxy outgrowths and is often puberulous or pubescent. In the Sunnabile group, it is more marked, often very distinct on each side, sometimes raised. It is usually covered by a dense or shaggy pubescence and sometimes has long hairs at the sides nearest the leaf edge. A study of the transverse marks, on the other hand, has not yielded any appreciable differences in the two groups.

(3) *Scabrous feel.* This is often a marked character at the tip of the leaf. It is especially noticeable on the upper, ventral aspect, in the members of the Sunnabile group. If one passes the fingers downwards in this region, the roughness of the leaf, depending on small siliceous points projecting upwards, reminds one of shagreen. There is also considerable, but less marked, roughness on the lower or dorsal side of the leaf tip. One marked exception, however, occurs, the leaf ends being practically glabrous in *Putli Khajee.* This is in fact similar to the Saretha group generally. The scabrous feel is very sligh: or absent above in this group and the roughness below is slight. In this character of the leaves the Saretha series, as usual, resembles *Saccharum spontaneum* in such specimens as have been examined.

(4) *Serrature.* Here also the greater hairiness or harshness of the leaves is noticeable in the Sunnabile group. With the exception of *Putli Khajee*, the serrature of the leaves is strong, harsh and persistent. In the Saretha series (as in *Saccharum spontaneum*), it is usually soft, fine and more or less deciduous. In the Sunnabile series the leaves, thus, have spines on the back of the sheath, rough callus, strong scabrous feel at the leaf tip and harsh persistent serrature, while the ligular setæ are strong and frequently long: in the Saretha series the leaves are glabrous or almost so in all these respects, and one would feel tempted to suspect a correlation between the development of strong hairs in all parts of the leaf. But the anomalous position of *Putli Khajee* suggest caution. It has spines on the back of its leaf sheath while its serrature agrees with that of the Saretha varieties. So also, in one of the two specimens of *Khadya* received from Bombay the leaf sheath is glabrous, and in the other it is spiny, and the glabrous-sheathed form agrees in other respects with the rest of the Sunnabile group.

(5) *Number of laminas.* As in the sheaths there are many more laminas in the Sunnabile group in 1916, but about the same in the two groups in 1917. The numbers in 1916 are, in Saretha 36, and in Sunnabile 45, whereas in 1917 the respective numbers are 29 and 30.

(6) *Length of lamina in different parts of the cane.* Here, as in the sheath, we have been led to consider the 1916 measurements as more in keeping with the known characters of the groups. The following are the figures obtained from the same canes which were measured for length of joint and length of leaf sheath :-

Average length of successive laminas, 1916, in inches :

Saretha group.	37, 39, 42, 45, 48, 51, 52, 53, 54, 55, 56, 55, 56, 56, 56, 57, 57, 57, 57, 56, 57, 57, 57, 57, 56, 55, 55, 54, 54, 53, 51, 48, 45, 37, 26, 17, 8.
Sunnabile group.	30, 33, 36, 38, 40, 42, 43, 44, 45, 46, 46, 46, 47 47, 47, 47, 47, 47, 47, 47, 47, 48, 48, 18, 48, 48, 48, 48, 47, 48, 47, 47, 47, 46, 45. 45, 44, 43, 42, 40, 38, 35, 24, 20, 15, 8.

(7) *Curves.* These figures have been plotted out in curves as usual (Chart IV). The curve in the Saretha group, in 1916, is higher, shorter, steeper at the ends than that in the Sunnabile group, agreeing in these respects with the curves of length joints and leaf sheath. The curve starts higher in the Saretha group

and ascends more rapidly. The maximum is reached in 15 joints in Saretha, against 21 joints in Sunnabile, and is 9″ greater. A comparison, however, of the lamina curve with those of joint and sheath, shows certain fundamental differences. With steep rise and fall the lamina curve remains more or less horizontal at the top and thus presents a generally flattened appearance, which appears to be characteristic of all mature lamina curves. Once the region of full grown leaves is reached, there is little variation in length from joint to joint, rendering difficult all attempts at finding correlations between the lengths of leaves and other organs in different parts of the canes. In both the joint and sheath curves, on the contrary, the rise is very rapid at first and, once the maximum has been reached, a continuous descent follows. The sheaths and joints are longest in the young cane and become continuously shorter as growth proceeds.

A study of the 1917 crop, in which a considerably larger number of varieties were studied in each group, bears these remarks out. But, as in the case of joint and sheath, the effect of immaturity and poorer growth is shown, and the curves are much lower and shorter and, so to speak, cut off in the middle, because of the fewness of organs developed. The following are the measurements obtained: -

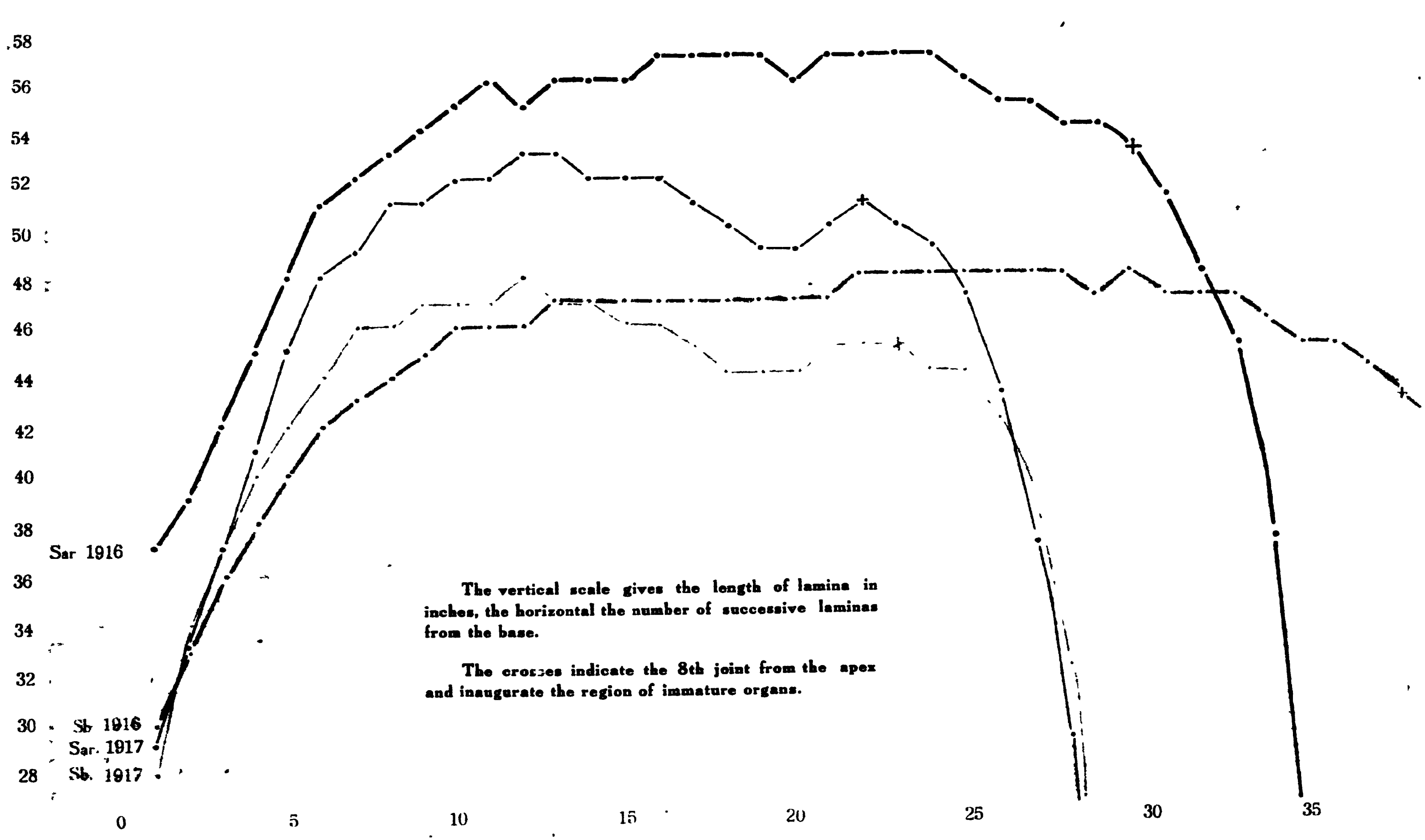
Average length of successive laminas, 1917, nine months old, in inches:

Saretha group. 29, 33, 37, 41, 45, 48, 49, 51, 51, 52, 52, 53, 53, 52, 52, 52, 51, 50, 49, 49, 50, 51, 50, 49, 47, 43, 37, 29, 21.

Sunnabile group. 28, 34, 37, 40, 42, 44, 46, 46, 47, 47, 47, 48, 47, 47, 16, 46, 45, 44, 44, 44, 45, 45, 45, 44, 44, 42, 39, 32, 21, 18.

(7) *Average length of mature lamina.* This was obtained from the above two series, leaving out the last 8 as possibly immature. The lengths in 1916 were, for Saretha 4′ 5″ and for Sunnabile 3′ 9″, and in 1917 Saretha 4′ 0″ and Sunnabile 3′ 8″. The leaves in the Saretha series are distinctly longer. A reference to the curves will show that it is possible that the lower figures in the nine months curves may be due to the fact that the longest had yet to come when the canes were measured. The maxima in lamina curves are considerably later than in joint and sheath curves, and the shortness of lamina in 1917 may not therefore be due entirely to poorer growth. The Mesangan section consists of much larger cane varieties than the Katha, and this is reflected in the length of lamina. In 1917 the average in the Katha section was 3′ 10″ and that of the Mesangan 4′2″, so that in this respect the intermediate nature of the latter section between the Katha section and the Sunnabile series cannot be gauged by mere length in inches.

CURVES SHOWING THE AVERAGE LENGTHS OF SUCCESSIVE LAMINAS FROM BASE TO APEX, IN THE SARETHA AND SUNNABILE GROUPS IN THE 1916 AND 1917 CROPS.



(8) *Width of leaf.* This varies along the length of the leaf and, in order to institute a just comparison, it has been found necessary to fix on the greatest width, in the measurements. This was estimated by spreading out the leafy shoot and selecting the widest leaf present. The figures therefore refer to the extreme width of the leaf. In 1916 the average extreme width was 1·5″ in the Saretha, and 1·8″ in the Sunnabile groups, while in 1917 the figures were 1·3″ and 1·7″ respectively. As in the case of length of leaf, it is possible that, here too, the widest leaves were still undeveloped in the measurements of the immature canes of 1917. The leaves in the Sunnabile group are considerably wider than those in the Saretha group. The Mesangan section appears to be intermediate between the Katha section and the Sunnabile group, but it must be remembered that it consists of bigger canes; the figures in 1917 were Katha section 1·2″, Mesangan 1·5″.

(9) *Leaf module.* This expression signifies here, as elsewhere, length divided by breadth. It is built up with the aid of figures contained in the last two paragraphs and is therefore average length divided by average extreme width. As might be expected, from our knowledge that the organs are longer and narrower in the Saretha series, the differences in the two groups are marked. The 1916 figures are Saretha 35, Sunnabile 25, and, in 1917, Saretha 37 and Sunnabile 26, resemblances sufficiently close to rule out all differences in vigour of growth. In spite of the poorer growth in 1917, the form of the leaf appears to have remained normal. The Mesangan section again occupies an intermediate position, the figures in 1917 being, Katha section 38, and Mesangan 33.

(10) *Leaf shape.* These are the main measurements of the lamina. But it was felt that the figures did not express obvious differences in *shape.* Most of the Saretha leaves show a marked narrowing above the base and the widest part of the Sunnabile leaf is, on the whole, lower down the length of the leaf than in the Saretha group. A series of width measurements were therefore made in the laboratory, in ten leaves of each variety, at different distances from the base. These distances were empirically selected at 1″, 6″, 12″ and at the widest part, wherever that was, and its distance from the base noted. It was surmised that these measurements would be sufficient for the purpose and that, from them, we should be able to form a correct idea of the form of the leaf in each class. To complete the picture, it was necessary to note the full length of each leaf measured, but this was unfortunately not appreciated in the 1916 measurements, and the omission has been filled in by taking the length of leaf obtained from the general curves of 20 canes measured in that year. The following are summaries of these measurements, it being noted

that *Khadya*, which was examined at a different time from the rest, has been omitted from the Sunnabile series.

Laboratory measurements of laminas in 10 canes of each variety, in inches.

	Width at base	At 1″	At 6″	At 12″	Widest place	Distance from base to widest place	Total length of leaf	REMARKS
1916								
Saretha group ..	0·95	0·79	0·88	1·03	1·39	25″	(4′ 5″)	Total length in 1916 taken from field measurements of 20 canes.
Sunnabile group	1·03	1·11	1·19	1·47	1·73	19″	(3′ 9″)	
1917								
Katha section ...	0 84	0 69	0·77	0·89	1·14	23·5″	4′ 3″	
Mesangan section	1·10	0·94	1·01	1·13	1·45	28·8″	4′ 10″	
Saretha group	0·94	0·79	0·87	0·98	1·26	25·6′	4′ 5″	
Sunnabile group	0·98	1·01	1·24	1·46	1·66	19″	3′ 10″	

From a study of this table we are able to draw a certain number of conclusions.

(*a*) In the Saretha group the narrowest part is 1″ above the base of the leaf. There is a marked pinching in above the base and the reverse is, if anything, the case in the Sunnabile series. Taking as an expression of this narrowing, $\frac{\text{width at base}}{\text{width at } 1'' \text{ from base}}$ we get the following :—

1916. Saretha group $\frac{95}{79}$, Sunnabile $\frac{103}{111}$.

$$\left.\begin{array}{ll}\text{1917. Katha section} & \frac{84}{69} \\ \text{Mesangan section} & \frac{110}{94}\end{array}\right\} \text{Average } \frac{94}{78}, \text{ Sunnabile } \frac{98}{101}.$$

(*b*) The widest part of the leaf is lower down (19″ from the base) in the Sunnabile series than it is in Saretha (25″ from the base), and the figures for the two years show marked similarity. But the Sunnabile leaf is shorter, and, to determine the proportional position of the widest part, it becomes necessary to include the average total length of leaf. Using as an expression of this the formula, $\frac{\text{distance from base to widest part}}{\text{total length of leaf}}$, we have as follows :—

1916.	Saretha group	·47	Sunnabile group	0·40
1917.	Katha section	.46		
	Mesangan section	·50		
	Saretha group	·48	Sunnabile group	0·41

Roughly, in the Saretha series, the widest part is half way up the leaf, and two-fifths of the way up in the Sunnabile. This emphasizes the shortness and broadness of the leaves in the latter series.

(c) A further expression of this feature may be obtained by an estimation of the rate of widening in the leaf, per unit of length. This upward gradient can be put in figures as follows :-

Upward gradient $= \frac{\text{greatest width} - \text{least width}}{2}$ in the distance from widest to narrowest part. The narrowest part may be safely taken as 1″ above the base in each case, so that the distance referred to in the formula will be the distance above the base of the widest part, less 1″. Working out the figures by the formula, we obtain the following for 1917. The actual total length of leaves was not taken in 1916.

1917.	Katha section	Gradient of	1 in 100
	Mesangan section		1 in 109
	Saretha group		1 in 102
	Sunnabile group		1 in 55

Thus the upward gradient of widening in the leaf is practically twice as steep in the Sunnabile series as it is in the Saretha.

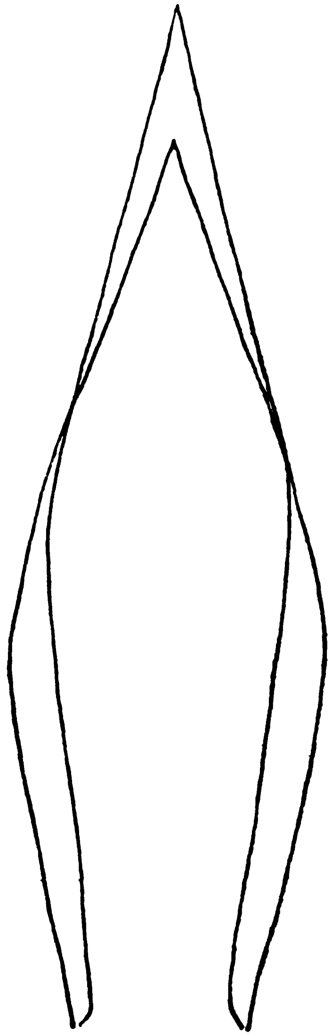
The downward gradient, from the widest point to the tip of the leaf, may be obtained in a similar manner, the formula being $\frac{\text{extreme width}}{2}$ in the difference between total length and distance of widest point from base of leaf. The 1917 figures give us the following :—

1917.	Katha section	1 in 18
	Mesangan section	1 in 10
	Saretha group	1 in 11
	Sunnabile group	1 in 33

The downward gradient is considerably steeper than the upward, but there is less difference in the two groups, that of the Saretha leaves being three-fourths that of the Sunnabile, instead of nearly one-half.

From the above study of leaf measurements we have thus succeeded in extracting new and stable differences in the form of the average leaf in the two groups, and this gives important support to the reality of the grouping of the varieties concerned. We are in a position to draw the outline of a typical leaf in each group, but the length is so enormously greater than the width, that some sort of compromise is necessary. I have accordingly drawn the two leaves to scale, multiplying the width by ten, and the

diagram shows the differences exaggerated, in the form of two greatly fore-shortened outlines.



OUTLINES OF LEAVES IN THE SARETHA AND SUNNABILE GROUPS, GREATLY FORE-SHORTENED. THE NARROWER, LONGER LEAF IS THAT OF THE SARETHA GROUP.

(11) *The midrib.* This is much more prominent in the Saretha leaves than in the Sunnabile, in this respect pointing to a marked resemblance in the former to the leaves of *Saccharum spontaneum*. To give an exact expression

of this relative prominence, the width of the midrib was measured at the same time and place as the width of the lamina in the above table. The midrib may be studied from two standpoints, firstly, its own intrinsic width, and, secondly, the relation this bears to that of the lamina.

(*a*) Width of midrib in different parts of the leaf.

		At 1″	At 6″	At 12″	At widest part of leaf	Distance from base to widest place
1916.	Saretha group ..	0·19	0·20	0·17	0·09	25″
	Sunnabile group	0·18	0·17	0·15	0·11	19″
1917.	Katha section . .	0·17	0·16	0·14	0·08	23·5″
	Mesangan section ...	0·20	0·20	0·19	0·12	28·8″
	Saretha group .	0·19	0·18	0·16	0·09	25·6″
	Sunnabile group	0·13	0·14	0·13	0·10	19″

We see from these figures that the midrib is distinctly wider in the leaves of the Saretha series all the way up, and this is the more noticeable when we remember that the leaves are wider in the Sunnabile group, especially in this lower part of the leaf.

(*b*) *Relative width of lamina and midrib.* To give expression to this the width of lamina has been divided at each point by the width of midrib. The following figures give the quotients :—

		At 1″	At 6″	At 12″	At widest part of leaf	Distance of widest part from base
1916.	Saretha group ..	4·2	4·4	6 0	15·4	25″
	Sunnabile group ..	5·5	7·1	11·4	16·7	19″
1917	Katha section ...	4·1	4·8	6·3	14·2	23·5″
	Mesangan section ...	4·7	5·0	5·9	12 1	28 8″
	Saretha group ...	4·2	4·8	6·1	14·0	25·6″
	Sunnabile group .	7·8	8·9	11·2	16·6	19″

And the table gives a useful expression of the comparative inconspicuousness of the midribs in the Sunnabile series.

TABLES OF MEASUREMENTS.

Average Measurements of Twenty Canes.

Varieties in the Saretha group, 1917, 9 *months old.*

	Number of joints with dead leaves	Length of cane with dead leaves	Length of living shoot	Total length of plant	Maximum width of leaf	THICKNESS OF CANE (Centimetres) (The thickness of cane was measured by calipers) — Bottom — Lateral	Bottom — Median	Middle — Lateral	Middle — Median	Top (Mature) — Lateral	Top (Mature) — Median	Average of the six preceding measurements
Katha Section												
Raksi ..	17	5 2″	5 9″	10 11″	1·0″	1 39	1·42	1·34	1·36	1·13	1·16	1·30
Katha ..	13	4′ 1″	5′ 11″	10′ 0′	1·0	1·44	1·48	1 40	1·45	1·27	1·32	1·39
Ramui ..	15	4′ 7″	5′ 10″	10′ 5″	1 2″	1·51	1·51	1·53	1·59	1·35	1·40	1·49
Lalri ..	14	5′ 1″	6 8′	11 8″	1·2″	1·31	1·37	1·38	1 45	1·36	1·42	1·38
Chin ..	15	4′ 7″	6 0	10′ 7″	1·2″	1·57	1·62	1·57	1 64	1·15	1·49	1·56
Chunnee ..	17	4 5″	5′ 2″	9 7″	1·0″	1·52	1·57	1·57	1 62	1·43	1 48	1 53
Baraukha ...	15	4′ 8″	6′ 4″	10′ 11″	1·3″	1·62	1·68	1·65	1·71	1 47	1 52	1·61
Kansar ..	14	5 3″	6 10′	12′ 1″	1·4″	1·59	1·64	1·61	1 66	1 49	1·54	1 59
Chynia ..	13	4′ 5″	7 2	11′ 6″	1 3″	1·72	1·77	1·70	1·75	1·51	1·56	1·67
Burra Chunnee ...	16	3′ 3″	7′ 3	10′ 5″	1 4″	1 73	1·75	1·72	1·76	1·60	1·63	1·70
Saretha (brown) ..	15	4 10′	6 5′	11′ 3″	1·3″	1·65	1·71	1·74	1·79	1·64	1·69	1·71
Average of section	**15**	**4 7″**	**6 4″**	**10 11″**	**1 2″**	**1·55**	**1·60**	**1 56**	**1·62**	**1·12**	**1·47**	**1·54**
Mesangan Section												
Mesangan ..	15	4′ 3″	6 2″	10′ 5′	1·1″	1·59	1·65	1·59	1·66	1 48	1·54	1 59
Saretha (green) ...	16	4′ 9′	6′ 5″	11′ 3″	1·3″	1·61	1·66	1·70	1·74	1·51	1·59	1 64
Jaganathia ..	12	4 6″	7′ 3″	11′ 9″	1·6″	1·68	1·74	1·78	1·82	1 56	1·61	1·70
Khari .	16	5′ 4″	7′ 2″	12′ 5	1·5″	1·99	2·05	1·98	2·04	1·68	1·74	1 91
Hullu Kabbu ..	12	4′ 4″	7′ 5″	11′ 9′	1·5″	1·86	1·92	1·95	2 01	1·66	1·71	1·85
Ganda Cheni ..	14	5′ 3″	8′ 0″	13′ 2″	1·9″	2 09	2·14	2·16	2·21	1·78	1·83	2·03
Kalkya .	15	5′ 5″	6′ 8	12′ 2″	1 8″	2·17	2·25	2·21	2 30	1 85	1·92	2·12
Average of section	**14**	**4 10″**	**7 0″**	**11′ 10″**	**1 5″**	**1·86**	**1 92**	**1·91**	**1·97**	**1·65**	**1·91**	**1 83**
Average of group	**15**	**4′ 8″**	**6′ 7″**	**11′ 3″**	**1 3″**	**1·67**	**1 72**	**1·70**	**1 75**	**1·51**	**1·56**	**1 65**

AVERAGE MEASUREMENTS OF TWENTY CANES.

Varieties in the Sunnabile group, 1917, 9 *months old*

	Number of joints with dead leaves	Length of cane with dead leaves	Length of living shoot	Total length of plant	Maximum width of leaf	THICKNESS OF CANE (Centimetres) (The thickness of cane was measured by calipers) — BOTTOM Lateral	BOTTOM Median	MIDDLE Lateral	MIDDLE Median	TOP (MATURE) Lateral	TOP (MATURE) Median	Average of the six preceding measurements
Teru	13	3 6	4 9"	8 5	1 4"	1 18	1 24	1 16	1 23	1 14	1 25	1 18
Rakhra	13	3 10	6 5"	10 4"	1 5	1 28	1 35	1 41	1 54	1 42	1 25	1 42
Ekar	17	4 7"	6 4"	10 9	1 5"	1 47	1 56	1 54	1 65	1 39	1 48	1 51
Dhaulu	15	3 10"	5 10"	9 8	1 4	1 34	1 39	1 [illegible]5	1 41	1 21	1 25	1 32
Kaghze	14	3 9	7 1"	10 9	1 6	1 59	1 67	1 68	1 78	1 62	1 93	1 71
Ketari	18	4 1	4 4"	8 5	1 6	1 43	1 47	1 51	1 52	1 46	1 52	1 65
Bansa	20	5 2	4 10	9 11	1 8	1 65	1 71	1 81	1 88	1 68	1 75	1 75
Bansi	13	3 6"	6 10"	10 1	1 8	2 06	2 11	2 12	2 17	1 83	1 89	2 03
Sunnabile	15	3 11	5 8	9 7	1 9	2 05	2 12	2 03	2 17	1 88	1 94	2 05
Puthi Khajee	18	5 7	6 10	12 5	1 8	2 17	2 24	2 33	2 41	1 97	2 03	2 19
Khadya	17	4 7"	6 4	10 11	1 7	2 [illegible]4	2 31	2 3	2 38	1 88	1 93	2 17
Naanal	19	4 9	6 2	10 11	1 6	2 10	2 15	2 16	2 21	1 81	1 86	2 05
Hotte Cheni	16	4 8	6 3	10 11	1 9	2 [illegible]4	2 31	2 [illegible]0	2 [illegible]6	1 97	2 03	2 [illegible]0
Dhoi	13	2 9	1 11	7 8	1 9	2 03	2 09	1 91	2 01	1 56	1 59	1 86
Mojorah	13	3 11	6 6	10 5	2 5	2 68	2 80	2 65	2 75	2 24	2 34	2 68
Average of group	**16**	**4 2**	**5 11**	**10 1**	**1 7**	**1 83**	**1 90**	**1 88**	**1 96**	**1 67**	**1 75**	**1.85**
Average of Saretha group	**15**	**4 8**	**6 7**	**11 3**	**1 3**	**1 67**	**1 72**	**1 70**	**1 75**	**1 51**	**1 56**	**1 65**

Average Measurements of Twenty Canes.

Varieties in the Saretha and Sunnabile groups, 1916, 13 *months old*.

	Number of joints with dead leaves	Length of cane with dead leaves	Length of living shoot	Total length of plant	THICKNESS OF CANE (Centimetres) (The thickness of cane was measured by calipers)						
					Bottom		Middle		Top (Mature)		Average of the six preceding measurements
					Lateral	Median	Lateral	Median	Lateral	Median	
Saretha Group											
Baraukha	23	8′ 2″	5′ 8″	13′ 10″	1·34	1·40	1·29	1·31	1·30	1·27	1·32
Ganda Cheni ...	21	7′ 11″	7′ 1″	15′ 1″	1·8[illegible]	1·96	1·97	2·13	1·94	2·10	1·82
Chin	25	7′ 5″	6′ 1″	13′ 6″	1·36	1·45	1·29	1·35	1·34	1·36	1·36
Hullu Kabbu ..	21	7′ 9″	6′ 9″	14′ 6″	1·91	2·02	2·00	2·11	1·93	2·07	2·01
Jaganathia ...	23	7′ 1″	6′ 2″	13′ 3″	1·61	1·71	1·70	1·77	1·74	1·84	1·73
Khari	22	6′ 11″	6′ 4″	13′ 2″	1·72	1·81	1·78	1·86	1·61	1·68	1·74
Saretha	28	7′ 10″	7′ 0″	14′ 10″	1·43	1·50	1·59	1·65	1·54	1·58	1·55
Average of group ..	23	7′ 7″	6′ 5″	14′ 0″	1·60	1·69	1·66	1·74	1·63	1·70	1·67
Sunnabile Group											
Bansa	38	8′ 10″	4′ 8″	13′ 8″	1·54	1·61	1·73	1·76	1·74	1·93	1·72
Bansi	32	6′ 10″	5′ 1″	11′ 11″	1·65	1·73	1·67	1·74	1·67	1·76	1·70
Dhor (Harrai) .	30	7′ 3″	6′ 5″	13′ 8″	1·96	2·03	2·04	2·15	1·99	2·05	2·04
Dhor (Seoni) ..	31	7′ 7″	6′ 5″	14′ 0″	2·14	2·22	2·30	2·39	2·17	2·26	2·25
Kaghze	32	6′ 10″	5′ 1″	11′ 11″	1·59	1·67	1·71	1·83	1·75	1·89	1·74
Ketari	30	7′ 0″	4′ 4″	11′ 4″	1·80	1·85	1·70	1·78	1·78	1·92	1·80
Naanal	29	7′ 0″	6′ 11″	13′ 10″	2·08	2·15	2·01	2·10	1·94	2·09	2·06
Putli Khajee	29	9′ 1″	6′ 1″	15′ 2″	1·98	2·15	2·00	2·15	2·07	2·31	2·11
Rakhra	31	7′ 4″	5′ 5″	12′ 8″	1·83	1·90	1·74	1·84	1·78	1·90	1·83
Sunnabile	30	6′ 11″	5′ 8″	12′ 7″	1·94	2·05	1·95	2·10	2·00	2·14	2·03
Average of group ...	32	7′ 5″	5′ 11″	13′ 4″	1·85	1·93	1·88	1·99	1·89	2·03	1·93

Average Measurements of Twenty Canes.

Varieties in the Saretha group, 1916 *and* 1917.

	1917 crop (9 months old)							1916 crop (13 months old)						
	Number of joints in cane up to ·1″	Number of sheaths	Number of laminas	Average length of joints	Length of stripped cane	Average thickness of cane	Cane module	Number of joints in cane up to ·1″	Number of sheaths	Number of laminas	Average length of joints	Length of stripped cane	Average thickness of cane	Cane module
				In.	In.	cm.					In.	In.	cm.	
Katha Section														
Raksi	26	29	29	3·7	79·9	1·30	154	...	.	.	.	..	..	.
Katha . ..	28	31	31	3 3	73·6	1·39	132	..		...	..	..	..	..
Ramui	25	27	27	3·6	70·4	1·49	118	.	..	...		...	...	..
Lalri	25	28	28	4·1	81·0	1·38	147		.	...	.	...	...	...
Chin	30	34	34	3·2	77·3	1·56	124	36	39	39	3·4	96·3	1·36	177
Chunnee	30	33	33	2·9	69·9	1·53	118	...	..	...		...	...	
Baraukha	25	28	28	3·8	74 9	1 61	116	32	34	35	4·3	102 9	1·32	195
Kansar	26	28	28	4·3	86·6	1·59	136	.			.		..	..
Chynia	26	28	28	4·0	81 8	1·67	122	...		..	.	...	. .	...
Burra Chunnee ..	28	33	33	2·4	54·3	1·70	80		...	..	..	..	...	...
Saretha (brown) ...	27	...	..	3 9	79·4	1·71	116	42	46	47	3·1	106 5	1·55	172
Average of Katha Section	**27**	**30**	**30**		**75 4**	**1 54**	**122**	...	.	..	...	...	...	..
Mesangan Section														
Mesangan	26	29	29	3·4	70 0	1·59	110	.	..	..		...	...	...
Saretha (green) ...	30	33	33	3·4	84·1	1·64	125	...		...	.		...	
Jaganathia ..	22	25	25	4 3	74 1	1 70	109	31	34	37	3·7	85·9	1·73	124
Khari	23	28	28	4·0	73·4	1·91	96	29	31	33	3 9	101·2	1·74	145
Hullu Kabbu ..	21	24	24	4·5	73 2	1·85	99	29	32	34	4·4	92 2	2 01	115
Ganda Cheni ...	22	26	26	4 6	75 6	2 03	97	28	32	33	4·5	95·4	1 82	131
Kalkya	27	..	34	4·1	83·1	2·12	98	...		..	.	.	...	..
Average of Mesangan section	**24**	**28**	**28**	...	**76 6**	**1 83**	**112**	..	.	.	...	..		..
Average of Saretha group	**26**	**29**	**29**	**3·8**	**75 9**	**1·65**	**115**	**32**	**35**	**37**	**3 9**	**97 2**	**1 67**	**146**

Average Measurements of Twenty Canes.

Varieties of the Sunnabile group, 1916 *and* 1917.

	1917 crop (9 months old)							1916 crop (13 months old)						
	Number of joints in cane up to 1″	Number of sheaths	Number of laminas	Average length of joints	Length of stripped cane	Average thickness of cane	Cane module	Number of joints in cane up to 1″	Number of sheaths	Number of laminas	Average length of joints	Length of stripped cane	Average thickness of cane	Cane module
				In.	In.	cm.					In.	In.	cm.	
Teru ...	25	29	29	2·7	53·8	1·18	114							
Rakhra .	24	29	28	3·4	62·2	1·42	109	40	43	46	2·9	92·4	1·83	128
Ekai .	26	31	31	3·3	69·7	1·51	115							
Dhaulu ..	28	32	32	2·8	62·4	1·32	118	31			2·8	65·3	.	
Kaghzo	25	30	30	3·2	66·0	1·71	96	39	43	43	2·6	80·4	1·74	116
Ketari	25			2·9	58·8	1·65	89	38	43	44	2·8	85·2	1·80	118
Bansa	29			3·1	75·6	1·75	108	43	48	49	3·1	107·4	1·72	156
Bansi	27	30	30	2·8	61·2	2·03	75	42	46	47	2·6	88·3	1·70	130
Sunnabile	27	32	32	3·0	66·0	2·03	81	44	47	47	2·6	94·1	2·03	116
Putli Khajee	29			3·6	84·7	2·19	97	35	40	41	3·8	105·2	2·11	125
Khadya	29	34	34	2·8	70·6	2·17	81		...	.				
Naanal	31	34	34	2·7	6[illegible]·3	2·05	83	42	47	47	3·0	103·4	2·06	125
Hotte Cheni	29	31	33	2·2	52·0	2·20	59	...	...		.			
Dhor	20	24	24	2·8	41·2	1·86	55	43	45	47	2·9	99·5	2·25	111
Mojorah .	24	28	28	3·6	67·3	2·68	63	...		.		.		
Average of Sunnabile group	**27**	**30**	**30**	**3·0**	**64·0**	**1·85**	**87**	**40**	**45**	**46**	**2·9**	**92·1**	**1·93**	**119**
Average of Saretha group	**26**	**29**	**29**	**3·8**	**75·9**	**1·65**	**115**	**33**	**35**	**37**	**3·9**	**97·2**	**1·67**	**146**

Average Measurements of Ten Leaves.

Varieties of the Saretha group, 1917.

(Measurements in Inches.)

	Leaf Sheath					Lamina												
	Clasping stem in terms of circumference	Width at base	Width at top	Length	Module	Width at base	Lamina at 1"	Midrib at 1"	Lamina at 6"	Midrib at 6"	Lamina at 12"	Midrib at 12"	Lamina at widest	Midrib at widest	Distance from base to widest part	Total length	Proportional height of widest part	Module
Katha section																		
Rakei ...	1 46	2 37	1·02	9 40	4 0	0·63	·50	·15	·56	·15	69	·11	·90	06	21	3 9"	·47	50
Katha .		3·04	1 15	10 20	3·3	0 78	·63	·15	·66	·14	·79	·12	·98	·07	22	3 9	·49	46
Ramui ..	1·49	2 72	1 26	10·30	3 8	0 92	·71	·18	·78	·18	·59	·16	1·06	·09	23	4 3"	45	51
Lahi	1·45	2·78	1·17	11·07	4·0	0 82	·71	·15	·77	·15	·79	·15	1·24	·06	28	4 4"	54	42
Chin	1·36	2 60	1·10	8 90	3 4	0·77	·68	·15	·81	·14	1·02	·12	1·19	·08	18	3 10"	39	39
Chunnee	1·44	2 60	1 20	8 70	3 3	0 80	·73	·17	·82	·15	·95	·13	1·03	·10	17	3 9"	·38	44
Baraukha	1 44	2·50	1 20	11·50	4 6	0 80	·68	·17	·77	·17	·86	·15	1·11	·07	25	4 7"	·46	50
Kansar	1 55	3·05	1 34	10 90	3·6	0 93	·81	·17	90	·15	1 07	·15	1·41	·08	27	4 8"	48	40
Chynia	1·57	2·98	1·25	12 30	4 1	0·87	69	·17	80	·17	·88	·15	1 25	·08	28	4 11"	48	47
Buria Chunnee	1·51	2 65	1·33	12·50	4 7	0·98	79	19	·87	·20	·98	·16	1·24	·11	24	4 4"	·46	42
Saretha (brown)	1·50	3·42	1·23	12 40	3·6	0·92	68	·17	·78	·16	·87	·14	1·08	·08	25·6	4 4	50	48
Average of section	1·48	2 79	1·11	10 74	3 8	0 84	69	17	·77	·16	89	·14	1·14	·08	23·5	4 3"	·46	45
Mesangan section																		
Mesangan	1·49	2·60	1 25	12·90	5·0	1·05	·88	·17	·93	·16	1·02	·15	1·12	·09	21	4 1"	·43	44
Saretha (green) ..	1·50	3 35	1·37	14·30	4 3	1 15	1·00	·15	1 07	·14	1·19	·14	1 22	·11	18 6	4 0	·40	39
Jaganathia	1·44	3·01	1·27	3 50	4·5	1 02	·83	22	·89	·22	1·01	·21	1 65	·07	39	5 0	·65	36
Khari	1 39	3 08	1·29	13 25	4·3	1·04	88	·19	1·00	·19	1·13	·18	1·58	·10	32	5 0	·53	38
Hullu Kabbu	1·42	3 06	1 42	14 65	4 8	1·06	·89	·19	·91	·18	1 05	·18	1·45	·11	30	5 3	48	43
Ganda Cheni	1 40	3·62	1 65	14·85	4·1	1·21	1·09	·23	1·21	·24	1·34	·21	1·75	·19	33	5 3	·52	36
Kalkya	1 38	3·43	1·53	13 40	3·9	1 20	1 00	·27	1·07	·27	1·18	·25	1·41	·15	28	5 0"	47	42
Average of section	1 43	3 16	1 40	13·84	4·4	1·10	·94	·20	1·01	·20	1·17	·19	1·45	·12	28·8	4 10	50	40
Average of group	1·46	2·93	1·22	11·95	4·1	0·94	·79	·19	·87	·18	·98	·16	1·26	·09	25·6	4 5	48	43

Average Measurements of Ten Leaves.

Varieties of the Sunnabile group, 1917.

(Measurements in inches.)

	Leaf Sheath					* Lamina												
	Clasping stem in terms of the circumference	Width at base	Width at top	Length	Module	Width at base	Lamina at 1″	Midrib at 1″	Lamina at 6″	Midrib at 6″	Lamina at 12″	Midrib at 12″	Lamina at widest	Midrib at widest	Distance from base of widest part.	Total length	Proportional height of widest part	Module
Teru	1·40	2·36	0·88	10·2	4·3	·65	62	·10	·86	·10	1·09	09	1·26	08	18	3 7	42	34
Rakhra ..	1·55	2·65	1·05	12·2	4·6	·73	·73	·11	·98	·12	1·19	·11	1·32	·07	20	3 4	50	30
Ekar . ..	1 43	2 86	1 06	12 9	4·5	·80	·80	·16	1·09	14	1·32	13	1·52	·11	17	3 11	36	31
Dhaulu ..	1·40	2·86	0·96	12·4	4 3	·67	·63	·10	·92	·11	1·22	·08	1 35	·06	17	3 5′	41	30
Kaghze .	1·37	2·77	1·09	12 3	4·4	·77	·84	·12	1·07	·12	1·27	·11	1·39	07	19	4 0	40	35
Ketari .	1 37	3 08	1 28	12·5	4·0	·99	·98	14	1·18	·16	1 36	·15	1·50	·11	17	3 7	40	29
Bansa .	1·37	3·27	1·34	10·5	3 2	1·01	1·12	·16	1 27	·16	1 45	·16	1 62	·10	21	4 2	42	31
Bansi	1·37	3·30	1·28	10 6	3·2	·99	·99	·12	1·45	·12	1 66	·10	1·83	·06	17	3 9	38	24
Sunnabile ...	1·33	3·27	1·19	11·1	3·4	92	·88	·13	1·23	·13	1·58	·11	1·84	·09	18	3 5	44	22
Putli Khajoe ...	1·37	3·89	1·75	13 3	3 4	1·48	1·49	·19	1·50	·18	1·56	·16	1 90	·10	25	4 3	49	27
Naanal ...	1·36	3·55	1·56	12·70	3 6	1·08	1·12	·14	1·33	·16	1·51	·16	1·74	·12	20	4′ 3′	39	29
Hotte Cheni ...	1·33	3 70	1·44	12·5	3·4	1·15	1·15	·13	1·32	·16	1·57	·16	1 83	·11	21	3 11	45	26
Dhor .	1·40	3·32	1·39	10 5	3·2	1 08	1 14	14	1 40	16	1 71	·14	1·84	·11	18	3 10	39	24
Mojorah	1·36	4·70	1 92	14·4	3·1	1 40	1·60	·15	1·79	20	2·05	·17	2·27	·17	18	4 4	35	23
Average of group	**1 39**	**3 26**	**1 30**	**12·0**	**3 7**	**98**	**1 01**	**13**	**1 24**	**14**	**1 46**	**13**	**1 66**	**10**	**19**	**3 10**	**41**	**28**
Average of Saretha group	**1 46**	**2 93**	**1 22**	**11 95**	**4 1**	**94**	**79**	**·19**	**87**	**18**	**98**	**16**	**1 26**	**09**	**25 6**	**4 5**	**48**	**43**

* These figures are not truly consistent, being obtained from different sets of measurements.

Average Measurements of Ten Leaves.

Saretha and Sunnabile groups, 1916.

(Measurements in inches.)

	Leaf Sheath: Clasping stem	Leaf Sheath: Width at base	Leaf Sheath: Width at top	Leaf Sheath: Length *	Leaf Sheath: Module *	* Lamina: Width at base	Lamina / Midrib 1″ fr. base	Lamina / Midrib 6″ fr. base	Lamina / Midrib 12″ fr. base	Lamina / Midrib At widest place	Distance from base to widest part	Total length *	Proportional height of widest part *	Module *
Saretha group														
Baraukha .	1·45	2·80	1·25	11·7	4·2	·84	64 / ·18	·75 / ·16	·91 / ·13	1·14 / ·07	24	4′ 2′	48	44
Ganda Cheni .	1·43	3·02	1·44	14 5	4·8	1·15	·94 / ·20	1·02 / ·23	1·15 / ·22	1·75 / ·11	34	5′ 0″	·57	34
Chin	...	2·78	1·02	9·7	3·5	·62	·62 / ·16	·82 / ·18	1·10 / ·13	1·28 / ·11	18	3′10″	39	36
Hullu Kabbu ..	1·45	3·24	1·28	13·7	3·1	1·09	·88 / ·19	·93 / ·21	1·14 / ·18	1·58 / ·11	23	4′ 9″	40	36
Jaganathia ...	1·16	3·44	1·15	12·6	3·1	1·03	·77 / ·24	·78 / ·25	·90 / ·25	1·57 / ·09	37	4′ 6″	67	34
Katha	1·51	3·22	1·16	.	...	·73	·63 / ·15	·66 / ·16	·79 / ·13	1·01 / ·06	21	..		..
Khari	1·36	3·22	1·40	12·9	4 0	1·17	·95 / ·26	1·09 / ·23	1·25 / ·21	1·63 / ·12	27	4′10″	47	36
Saretha ...	(·150)	3·00	1·11	12·0	4·0	·95	·85 / ·17	·95 / ·16	1·00 / ·13	1·13 / ·09	19	4′ 1″	·39	43
Average of Saretha group	**1·45**	**3 09**	**1·23**	**(12·4)** *	**(3·8)** *	**·95**	·79 / **·19**	·88 / **·20**	1·03 / **·17**	1·39 / ·09	**25**	(4′ 5″) *	(47) *	(38) *
Sunnabile group														
Bansa ...	(1 21)	3·38	1·35	12·0	3·6	...	1·01 / ·24	1·15 / ·22	1·36 / ·19	1·50 / ·13	22	3 11″	47	31
Bansi	1·33	2·92	1·17	10·1	3·5	·99	·84 / ·18	1·12 / ·15	1·60 / ·16	1·78 / ·12	15	3′ 3″	·38	22
Dhaulu . ..	1·43	2·68	1·0)	.	..	·66	·70 / ·13	·94 / ·12	1·15 / ·10	1·22 / ·08	14	...		
Dhor (Harrai) .	1 33	3·44	1·50	11·4	3·3	1·02	1·02 / ·16	1·19 / ·18	1 51 / ·16	1·75 / ·12	19	4′ 1″	38	28
Dhor (Seoni) ..	1·45	3·83	1·66	12·3	3·2	1·30	1·29 / ·22	1·45 / ·23	1 65 / ·21	2·07 / ·13	23	4′ 5″	·43	26
Kaghze ...	1·33	3·08	0·99	12·6	4 1	·72	·73 / ·13	·87 / ·15	1·17 / ·14	1·37 / ·08	18	3 8	42	32
Ketari .	...	...	...	10·7	...	...	...	...	..		.	3′ 2		
Mojorah ...	1·39	4·74	(1·70)	..	...	1·45	1·46 / ·20	1·76 / ·19	1 92 / ·19	2·25 / ·16	20	..	...	
Naanal	1·33	3·36	1·22	12·6	3·8	...	.. / ...	... / ...	. / ...	.. / ...	...	3′11″	.	
Putli Khajee ...	1·38	3·64	1·72	13·7	3·8	1·34	1·19 / ·22	1·22 / ·21	1·47 / ·17	2·07 / ·09	23	4′ 5	43	26
Rakhra	1·37	2·86	1·29	11·1	3·7	·90	·79 / ·14	1·02 / ·15	1·16 / ·12	1·39 / ·08	18	3′ 6′	13	30
Sunnabile ...	(1·30)	3·14	1·16	10·8	3 4	·88	·92 / ·15	1·20 / ·14	1·71 / ·11	1·86 / ·08	18	3 5	11	22
Average of Sunnabile group.	**1·35**	**3 37**	**1·34**	(11·7) *	(3·6) *	**1 03**	1·10 / **·18**	1·19 / **·17**	1·47 / **·15**	1·73 / **·11**	19	(3 9) *	(42) *	(27) *

* These figures are not truly consistent, being obtained from different sets of measurements.

Average lengths of successive joints. Varieties of the Saretha Group, 1917.

Katha section	(Measurements in inches)																														Number of joints
Raksi ..	4·4	4·7	4·8	5·2	4·7	4·1	4·0	3·9	4·1	3·7	3·5	3·0	2·5	2·5	2·7	2·9	3·1	3·0					3·0	2·7	2·3	2·2	1·9	0·7	0·2	0·1	26
Katha ..	3·4	4·3	4·5	4·4	4·2	4·2	4·1	4·0	3·7	3·8	3·6	3·1	2·7	2·5	2·5	2·5	2·5	2·4	2·3	2·1			1·9	1·6	1·2	0·9	0·6	0·3	0·2	0·1	28
Ramui ..	3·5	3·6	3·8	4·0	4·0	3·8	3·7	3·4	3·6	3·7	3·7	3·8	3·6	3·4	3·4	3·1	3·0						2·4	1·9	1·6	1·4	1·0	0·5	0·2	0·1	25
Lalri ..	3·6	4·4	4·8	4·8	5·0	5·1	4·4	4·1	4·3	4·3	4·0	3·7	3·7	3·5	3·3	3·3	3·3						3·2	2·7	2·1	1·3	1·0	0·7	0·3	0·1	25
Chin ..	3·5	3·9	4·5	4·4	4·4	4·5	4·3	4·1	3·9	3·6	3·3	3·3	3·3	2·8	2·8	2·5	2·6	2·2	2·1	1·9	1·7	1·6	1·4	1·1	1·0	1·1	0·8	0·4	0·2	0·1	30
Chunnee ..	3·1	3·7	4·0	4·1	4·3	4·2	4·0	3·7	3·3	3·1	2·9	2·5	2·2	2·5	2·3	2·1	2·1	1·9	2·0	2·0	1·9	1·6	1·5	1·3	1·1	1·0	0·8	0·4	0·2	0·1	30
Baraukha ..	3·3	3·8	4·0	4·3	4·2	4·3	4·1	4·3	4·4	4·0	3·4	3·2	3·5	3·6	3·1	3·2	3·3						2·6	1·8	1·3	1·3	0·9	0·4	0·2	0·1	25
Kansar ..	4·1	4·8	5·1	5·0	5·1	5·1	5·0	4·6	4·6	4·2	4·2	4·0	3·8	3·6	3·8	3·6	3·4	2·9					2·9	2·3	1·6	1·0	0·8	0·4	0·2	0·1	26
Chynia ..	3·8	4·1	4·4	4·5	4·6	4·5	4·4	4·3	4·6	4·2	3·7	3·4	3·8	3·7	3·6	3·5	3·3	3·4					2·9	2·1	1·9	1·5	0·9	0·4	0·2	0·1	26
Burra Chunnee	3·0	3·0	2·8	2·8	3·0	2·8	2·7	2·7	2·5	2·3	2·1	2·0	2·2	2·2	2·3	2·2	2·0	1·9	1·8	1·8			1·7	1·3	1·0	0·8	0·7	0·4	0·2	0·1	28
Saretha ..	4·0	4·8	4·9	5·0	4·9	4·8	4·6	4·1	3·8	3·6	3·4	3·2	2·7	2·6	2·9	3·1	3·0	2·9	2·6				2·4	1·8	1·3	1·1	1·1	0·5	0·2	0·1	27
Av. of section	3·6	4·1	4·3	4·4	4·1	4·3	4·1	3·9	3·9	3·7	3·4	3·2	3·1	3·0	3·0	2·9	2·9	2·5	2·4				2·4	1·9	1·5	1·2	1·1	0·5	0·2	0·1	27
Mesangan section																															
Mesangan ..	3·2	4·2	4·7	4·4	4·1	3·7	3·6	4·1	4·3	4·0	3·4	2·6	2·4	2·3	2·2	2·4	2·5	2·4					2·3	2·3	1·9	1·3	0·9	0·5	0·2	0·1	26
Sarotha ..	3·5	4·0	4·5	4·5	4·5	4·1	3·8	3·7	3·6	3·5	3·3	3·0	2·9	2·9	2·7	3·0	3·1	2·9	2·8	2·7	2·6	2·5	2·6	2·6	2·0	1·4	0·7	0·4	0·2	0·1	30
Juganathia ..	3·4	3·8	4·2	5·0	5·0	4·6	4·5	4·5	4·5	4·6	4·2	4·0	4·1	3·9									3·6	3·6	3·0	2·0	1·1	0·5	0·2	0·1	22
Khari ..	2·9	3·3	3·8	4·2	4·7	4·6	4·8	4·4	4·4	4·2	4·2	4·2	3·8	3·7	3·4								3·1	3·2	2·8	1·9	1·1	0·4	0·2	0·1	23
Hullu Kabbu	3·0	4·0	3·9	4·2	5·0	5·2	5·1	4·7	4·6	4·7	4·8	4·6	4·4										4·7	3·9	2·6	1·9	1·1	0·5	0·2	0·1	21
Ganda Choni	2·6	3·4	4·4	5·5	5·6	4·7	5·0	4·7	5·2	5·0	5·0	4·7	4·5	4·3									4·2	3·4	2·6	1·8	1·1	0·6	0·2	0·1	22
Kalkya ..	3·4	4·0	4·8	4·8	4·8	5·0	5·0	4·7	4·9	4·3	4·3	4·2	4·1	3·9	3·8	3·4	2·9	2·4	1·9				1·5	1·2	1·1	1·0	0·7	0·4	0·2	0·1	27
Av. of section	3·4	3·8	4·3	4·7	4·8	4·6	4·5	4·4	4·5	4·3	4·2	3·9	3·7	3·5	3·4	3·2							3·1	2·9	2·3	1·6	1·0	0·5	0·2	0·1	24
Av. of group ..	3·4	4·0	4·3	4·5	4·6	4·4	4·3	4·4	4·4	3.9	3·7	3·5	3·3	3·2	3·0	2·9	2·9	2·8					2·7	2·3	1·8	1·4	1·0	0·5	0·2	0·1	26

For curves of the Sarotha and Sunnabilo group averages, see pages in Detailed List of Characters.

Average lengths of successive joints. Varieties of the Sunnabile Group, 1917.

(Measurements in inches)

Variety				Number of joints
Toru	..	3·2 3·1 3·2 3·4 3·6 3·9 3·7 3·5 3·0 2·6 2·3 2·1 1·9 1·7 1·7 1·5 1·5	1·7 1·9 1·6 1·3 0·7 0·4 0·2 0·1	25
Rakhra	..	3·8 4·1 4·1 4·0 3·8 3·8 3·9 3·7 3·5 3·1 3·0 3·1 2·8 2·4 2·2 2·4	2·2 2·0 1·6 1·3 0·7 0·4 0·2 0·1	24
Ekar	..	3·2 3·4 3·5 3·7 3·8 3·9 4·0 3·8 3·6 3·4 3·2 3·0 2·9 2·7 3·1 2·9 2·7 2·5	2·6 2·4 2·3 1·6 0·8 0·4 0·2 0·1	26
Dhaulu	..	3·2 3·3 3·7 3·5 3·2 2·9 3·0 3·1 3·4 3·1 2·8 2·5 2·2 2·0 2·3 2·5 2·3 2·3 2·1 2·1	1·8 1·5 1·3 1·0 0·6 0·4 0·2 0·1	28
Kaghze	..	2·2 3·1 3·6 3·7 3·5 3·3 3·5 3·7 3·8 3·5 3·3 3·1 2·9 2·9 2·8 2·8 2·5	3·1 2·8 2·5 1·8 0·9 0·4 0·2 0·1	25
Ketari	..	2·4 2·8 3·1 3·5 3·5 3·1 2·8 3·1 3·2 3·3 3·4 3·0 2·7 2·6 2·6 2·4 2·2	2·0 1·7 1·9 1·5 1·1 0·6 0·2 0·1	25
Bansa	..	2·9 3·2 3·1 3·6 3·7 3·7 3·7 3·3 3·2 3·3 3·3 3·5 3·4 3·2 3·0 2·7 2·7 2·7 2·6 2·5 2·4	2·4 2·1 1·9 1·5 0·9 0·5 0·2 0·1	29
Bansi	..	2·3 2·6 2·8 2·9 3·0 3·0 3·1 3·4 3·2 3·1 3·1 3·0 2·9 2·8 2·9 2·7 2·5 2·3 2·1	1·9 1·5 1·5 1·4 0·7 0·5 0·2 0·1	27
Sunnabile	..	2·8 3·1 3·2 3·3 3·0 3·1 3·1 3·4 3·4 3·6 3·4 3·1 3·0 2·9 2·9 2·7 2·7 2·6 2·4	2·0 1·8 1·6 1·2 0·9 0·5 0·2 0·1	27
Putli Khajee	..	2·7 3·3 3·4 3·6 3·7 3·9 3·9 3·9 3·9 4·0 4·1 4·0 3·8 3·7 3·5 3·4 3·4 3·3 3·4 3·8 3·2	2·5 2·0 1·6 1·2 0·8 0·4 0·2 0·1	29
Khadya	..	2·1 2·5 2·9 3·2 3·3 3·4 3·5 3·3 3·2 3·1 3·1 3·1 3·1 3·0 2·8 2·7 2·6 2·5 2·4 2·1 1·9 2·0 1·8	1·3 1·4 1·6 1·3 0·7 0·4 0·2 0·1	31
Naanal	..	1·9 2·3 2·3 2·4 2·8 3·1 3·1 3·0 2·8 2·8 2·9 3·2 3·2 3·0 2·7 2·8 2·8 2·8 2·6 2·6 2·5 2·1 1·8	1·6 1·6 1·3 0·9 0·7 0·4 0·2 0·1	31
Hotte Cheni	..	2·6 3·2 3·2 3·3 3·3 3·5 3·5 3·6 3·6 3·7 3·6 3·5 3·5 3·3 3·3 3·4 2·9 2·5 2·3 2·0 1·8	1·6 1·4 1·2 0·9 0·6 0·4 0·2 0·1	29
Dhor	..	2·5 2·9 3·0 3·2 3·2 3·0 2·7 2·6 2·6 2·6 2·5 2·4	1·9 1·8 1·6 1·2 0·8 0·4 0·2 0·1	20
Mojorah	..	3·1 3·6 3·9 4·4 4·2 4·2 4·3 4·2 4·2 3·8 3·4 3·3 3·3 3·0 2·8 2·5	2·2 1·9 1·6 1·6 1·0 0·5 0·2 0·1	24
Av. of group	..	2·7 3·1 3·3 3·4 3·4 3·5 3·5 3·4 3·4 3·3 3·2 3·1 3·0 2·8 2·8 2·7 2·4 2·3 2·2	2·1 1·9 1·7 1·3 0·8 0·4 0·2 0·1	27

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Memoirs of the Department of Agriculture in India

Studies on Rice in Sind, Part I

BY

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PREFACE.

The rice breeding work in Sind was started in the harvest season of 1921 by Mr. T. F. Main, B.Sc., O.B.E., then Deputy Director of Agriculture in Sind, when a large number of single earheads in 10 varieties of Sind rice had been selected. These were handed over to me for study in February 1922 when the work was placed in my charge. More material was collected by me in the following season. By the end of 1923 I prepared a note embodying my work regarding classification and description of Sind rices, their morphological and agronomic characters, problems of fertilization and sterility and selection and testing of strains in the three principal local varieties. This note was then submitted by me for publication as a memoir but I was advised by the Director of Agriculture, Bombay, to postpone the publication till I had obtained more comprehensive data on the subject of selection and breeding of improved strains which after all was the ultimate object of the study.

At this stage Mr. Durgadutt joined me as Graduate Assistant for rice breeding and since then, from 1924, we concentrated our attention on further work of selection and breeding in Sind rice and also on acclimitization of foreign rices. The data then obtained were incorporated by me in my original note. For the assistance rendered by Mr. Durgadutt I am thankful to him and have associated his name as joint author.

I also acknowledge my indebtedness to Mr. T. F. Main, B.Sc., O.B.E., for his encouragement during the early part of this work and to Dr Harold H. Mann, D.Sc., for his valuable help in presenting this memoir in its present form.

K. I. THADANI,

Botanist, Agricultural Research Station, Sakrand (Sind).

CONTENTS

PLATES

STUDIES ON RICE IN SIND, PART I.

BY

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(Received for publication on 25th July 1927.)

I. Introduction.

By far the most extensively grown crop in Sind is rice, though this province has, in no part, where rice is cultivated, a greater average rainfall than ten inches per annum. As a result, it is exclusively an irrigated crop, depending at present on the flow in inundation canals from the river Indus, in which water is avaliable, as a rule, only from June to September. In spite of this limitation, the total area under the crop is about one and a quarter million acres, divided between two tracts of very different character, widely separated from one another. Fig. I shows the distribution and the relative intensity of rice cultivation in these tracts in the last year for which we have records, and the following table indicates the areas in the different Districts.

District	Area in 1925-26 Acres
Larkana	412,274
Sukkur	78,933
Upper Sind Frontier	111,285
Nawabshah	36,443
Hyderabad	261,717
Thar and Parkar	61,203
Karachi	240,907

RICE.

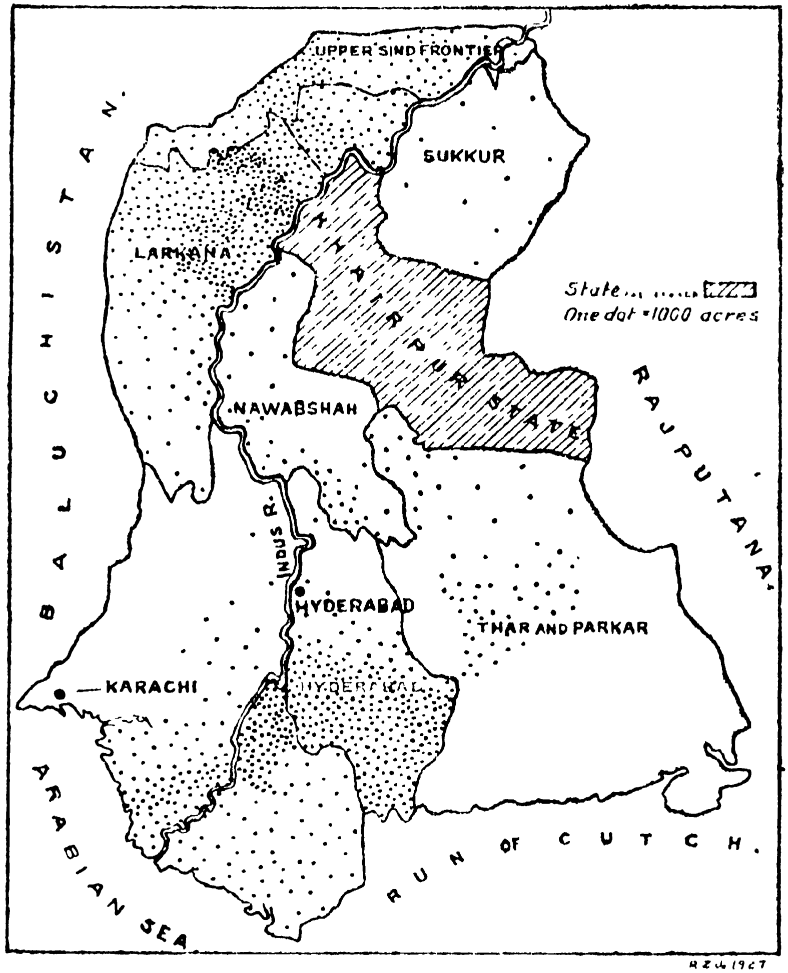


FIG. 1. Distribution of rice crop in Sind.

The Upper Sind rice tract is centred on the Larkana District, but extends into the Sukkur and Upper Sind Frontier Districts. These are among the hottest areas in India, but are supplied with water by flow irrigation in the inundation season. The land is alluvial and is usually well drained naturally. The conditions are very suitable for rice cultivation, yields up to 3,200 lb. of grain per acre are not uncommon, and high class rice is grown. Almost all the crop is transplanted from nursery beds.

The Lower Sind rice is grown in an area which is, to a great extent, actually in the delta of the Indus, with an extension to the east into the Nara valley. It com

prises the lower parts of the Hyderabad and Karachi Districts (known as the '*Lar*') and a portion of the Thar and Parkar District. The area differs from Upper Sind in a considerably cooler climate during the rice growing season, both by day and night, and far more moist atmospheric conditions. The water is much less under control than Upper Sind, and hence the rices have to be and are adapted for the deep water conditions which prevail in a large part of the tract. The crop in the Nara valley and in a large part of the *Lar* is broadcasted ; in the remainder of the *Lar* it is transplanted as in Upper Sind.

The varieties of rice grown are, as would be judged, very various and widely differing in character, and the object of the present paper is to present, on the one hand, a classification and short description of the special characters of the various types which have been found, and on the other, to describe the investigations which have been made on three of the more important varieties grown in Upper Sind, and on their improvement. These three varieties are *Kangni*, a type which occupies seventy-five per cent. of the area under the crop in Upper Sind, and *Jajai* and *Prong* two commonly grown so called *sugdasi* or flavoured varieties.

II. Classification of varieties of rice in Sind.

Species of rice in Sind. Though almost the whole of the rice found in Sind, cultivated or wild, belongs to the species *Oryza sativa*, yet there occurs in the delta—in the Shah Bunder taluka and the Keti Bunder mahal of the Karachi District—a wild species which has been named *Oryza coarctata* or *Oryza triticoides*. Its occurrence is limited to the swamps of the Indus delta where salt water mingles with fresh water. There the plant is known as *suan* grass, and the grain as *nanoi*. The mature grain sheds completely, and is gathered by the local inhabitants for food, while the straw is eaten by cattle, especially by buffaloes. The grain resembles wheat, and is stated by Watt to be carried all over India by Hindus for use on certain ceremonial occasions.

No further reference need be made to this special wild form of *Oryza*. There are, however, very many varieties of *Oryza sativa*, or rice proper, both wild and cultivated. The wild forms often appear as weeds in cultivated rice, and are frequent sources of contamination. Most of the wild types are characterised by the presence of long, very rough and stout awns, which are usually red or even scarlet, in colour, and all have the character of shedding most or all of their grain.

The cultivated varieties of rice in Sind are many, and thirty-five of these have been classified in the following table. In this table, the first distinction has been made between bearded and beardless rices, and then the following characters[1] have been used in succession in separating the various types :—

(*a*) Colour of leaf sheath - green or red.
(*b*) Colour of grain—white or red.

[1] These characters, as applied to Sind rices, are discussed fully on pages 121—138.

(*c*) Character of grain--long, fine or coarse.
(*d*) Colour of inner glumes, white, yellow, red, or black.
(*e*) Colour or lack of colour of the *tip* of inner glumes.
(*f*) Colour or lack of colour of the outer glumes.

Using the characters named, in this order, it has been possible to bring all the known varieties of rice in Sind into one comprehensive scheme.

BEARDLESS VARIETIES.

I. Rice with green leaf sheath.
1. Grain white.
B. Grain fine.
(*a*) Inner glumes white.
(i) apiculus and outer glumes colourless.
Variety I. *Parsad.*
,, II. *Barsati.*
(*b*) Inner glumes yellow.
(i) apiculus and outer glumes colourless.
Variety III. *Jirashahi.*
(ii) apiculus and outer glumes coloured.
Variety IV. *Jajai.*
,, V. *Unnamed new Type A* (*Sugdasi*).
,, VI. *Chajrai.*
,, VII. *Unnamed new Type X.*
(*c*) Inner glumes red.
(i) apiculus and outer glumes colourless.
Variety VIII. *Red Kangro.*
,, IX. *Bidri.*
,, X. *Sathri.*
(ii) apiculus and outer glumes coloured.
Variety XI. *Ratrya.*
C. Grain coarse.
(*a*) Inner glumes white.
(i) apiculus and outer glumes colourless.
Variety XII. *Ganjro.*
(*d*) Inner glumes black.
(i) apiculus and outer glumes coloured.
Variety XIII. *Pista* or *Kariaro.*

II. Rice with red leaf sheath.

1. Grain white.

B. Grain fine.

(*a*) Inner glumes white.

(i) apiculus and outer glumes colourless.
Variety XIV. *Kangni.*
" XV. *Sathrya.*

C. Grain coarse.

(*a*) Inner glumes white.

(i) apiculus and outer glumes colourless.
Variety XVI. *Kanjro.*
" XVII. *Torh.*

2. Grain red.

B. Grain fine.

(*a*) Inner glumes white.

(iii) apiculus coloured and outer glumes colourless.
Variety XVIII. *Unnamed New Type G.*

C. Grain coarse.

(*a*) Inner glumes white.

(i) apiculus and outer glumes colourless.
Variety XIX. *Sindhi kambroo.*

(iv) apiculus coloured and outer glumes colourless.
Variety XX. *Unnamed New Type Y.*
" XXI. *Ganja.*
" XXII. *Lari.*
" XXIII. *Motya.*

BEARDED VARIETIES.

I. Rice with green leaf sheath.

1. Grain white.

A. Grain long.

(*b*) Inner glumes yellow.

(i) apiculus and outer glumes colourless.
Variety XXIV. *Sighro.*

(*c*) Inner glumes red.

(i) apiculus and outer glumes coloured.
Variety XXV. *Sonahiri.*
" XXVI. *Sada Gulab.*

B. Grain fine.

(*a*) Inner glumes white.

(i) apiculus and outer glumes colourless.

Variety XXVII. *Unnamed New Type B.*

(*b*) Inner glumes yellow.

(ii) apiculus and outer glumes coloured.

Variety XXVIII. *Unnamed New Type C.*

" XXIX. *Piong.*

" XXX. *Bengalo.*

C. Grain coarse.

(*a*) Inner glumes white.

(iii) apiculus colourless and outer glumes coloured.

Variety XXXI. *Motiaro.*

II. Rice with red leaf sheath.

2. Grain red.

B. Grain fine.

(*a*) Inner glumes white.

(ii) apiculus and outer glumes coloured.

Variety XXXII. *Unnamed New Type Za.*

C. Grain coarse.

(*a*) Inner glumes white.

(i) apiculus and outer glumes colourless.

Variety XXXIII. *Unnamed New Type, D.*

(iv) apiculus coloured and outer glumes colourless.

Variety XXXIV. *Unnamed New Type Z.*

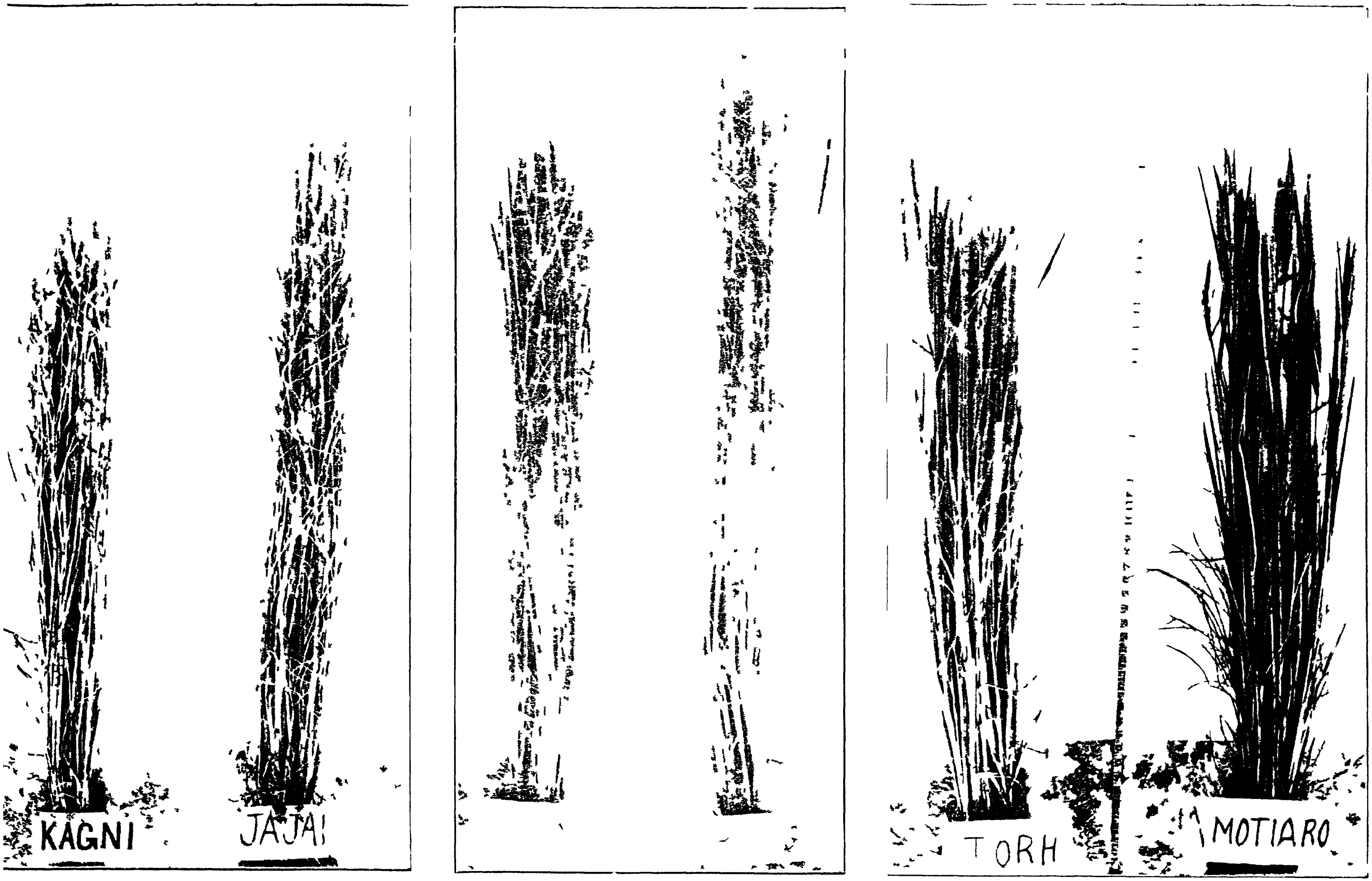
(*d*) Inner glumes black.

(ii) apiculus and outer glumes coloured.

Variety XXXV. *Unnamed New Type E.*

This table represents the whole of the types of rice which have reached the author's hands from various parts of Sind. It will be seen that they present great variety. Out of the thirty-five varieties twenty-three are beardless, and twelve bearded. The leaf sheath is green in twenty-one and red in fourteen cases. Twenty-five rices have white grains, and ten have red grains. Thirteen types are classed as coarse. Twenty-seven types were obtained in Upper Sind, and nine in Lower Sind.

DESCRIPTION OF RICE VARIETIES. The following notes indicate the status of each of these varieties in the cultivation of the crop.



1 2 3 4 5 6.

BEARDLESS VARIETIES.

I. *Parsad.* A sample of this variety was obtained from a Zemindar in the Larkana district. It is also known as *Sukh Parsad.* Its grain is fine and white, and it is *early.* The straw is strong. It is not grown on a commercial scale.

II. *Barsati.* This is a Lower Sind rice and was obtained from Tando Ghulam Hyder (Lower Hyderabad). It gives a fine white grain, is early and yields fairly well. It is not grown on a very large scale.

III. *Jirashahi.* This also comes from Hyderabad. Its grain is very small, hence its name which implies resemblance to a cuminseed. It ripens late, has strong straw and has a large tillering capacity. It is not grown on a commercial scale.

IV. *Jajai.* This is an important, scented, *sugdasi* variety ranking among the highest quality rices of Upper Sind. It usually brings a premium of Rs. 4 per maund of clean rice over *Kangni.* It is earlier than *Prong,* a *sugdasi* rice grown in the same area, but tends to lodge. The straw is very tough (and hence threshing is tedious), and it is not liked by cattle. The area under this variety is not very large, being chiefly in the Mirokhan and Kambar talukas of Larkana. Its yield is low compared to *Kangni* and *Prong.*

V. *Unnamed new type A.* This is a new *sugdasi* type discovered as a strong plant, which has a fine grain like *Jajai.* It is very early but is a poor yielder and shows much sterility.

VI. *Chajrai.* This is a Lower Sind rice, not grown on a large scale. Its grain is fine and white, but it is a poor yielder. It is a medium ripener.

VII. *Unnamed new type X.* This is a *Sugdasi* type found in a field of *Jajai,* ripening earlier than the latter. It is scented and yields fairly well, and the grain is fine and white.

VIII. *Red Kangro.* This is an early Upper Sind variety with a superior white grain, though with a red husk. The yield is higher than the common quick maturing types. It is not grown on a large scale.

IX. *Bidri.* This early rice, grown in Larkana on high lands, is a dwarf variety with a coarse grain. It can withstand a good deal of salt in the soil. It is grown on a fair scale on high lying lands.

X. *Sathri.* This variety, commonly grown on high lying lands in Upper Sind, is early ripening, but gives a poor grain, though its straw is much liked by cattle. It can withstand a good deal of salt in the soil.

XI. *Ratrya.* This is a variety common in the Nara valley, where it is known as Nara rice. It is also grown in the Tando area of Hyderabad under the name '*Khorwa*' rice. It is the best in quality of Lower Sind rices, giving a white medium quality grain and yields fairly well. It has a very light husk.

XII. *Ganjro.* This is a very early Upper Sind variety which is grown on high lands in small patches. Its grain is coarse, and the straw is brittle but much liked by cattle.

XIII. *Pista or Kariaro.* This variety is termed *Pista* owing to its small grain resembling a pistachio nut, and *Kariaro* on account of its black husk. It is an Upper Sind type, and is tall, late in maturity, and yields fairly well.

XIV. *Kangni.* This is the standard type of rice for Upper Sind, and is grown on all kinds of soils except those which lie low. The grain is white, medium in quality and the straw is good. It forms the staple food of the mass of the population, and is parboiled and then exported on a large scale.

XV. *Sathrya.* This is a type very similar to *Kangni* in the Nara Valley in Lower Sind. It gives a tall plant which lodges badly, matures early and only gives a small yield.

XVI. *Kunjro.* This Upper Sind variety is very rarely grown. It is late type, has a medium sized plant, with a white, small but coarse grain.

XVII. *Torh.* This is an important variety in Upper Sind for high lands, and it can withstand salt in the soil fairly well. It is a heavy yielder and has good straw, but sheds its grains badly. The grain is coarse and fetches a low price in the market.

XVIII. *Unnamed new type G.* This was found as a stray plant, with a fine red grain, in a field of *kangni* rice. It did not breed true, but a type as described has been isolated and maintained.

XIX. *Sindhi Kambroo.* This is an early variety from Lower Sind, with coarse red grains—not extensively grown.

XX. *Unnamed new type Y.* This was again found as a stray plant, and has been maintained. It is a type with a very heavy grain, yielding high and giving a coarse red grain.

XXI. *Ganja.* This is a Lower Sind variety grown on high lands, maturing earlier than *Motya* (*see* below). It lodges very badly, its grain is rather coarse and brittle and is very low priced.

XXII. *Lari.* This is an Upper Sind variety whose name implies that it was originally obtained from Lower Sind. It is grown on *low* lands, and the plant is tall and matures late. It lodges very badly. The grain is very poor and sells at a very low price.

XXIII. *Motya.* This is a low land variety from the South of the Hyderabad District. It is a tall plant and matures late. The grain is coarse, red and heavy, and fetches a low price. It is largely used in Hyderabad.

Bearded varieties.

XXIV. *Sighro.* This is an Upper Sind variety, early ripening and occasionally grown on patches on high lying land. The plants are not tall and the straw is much liked by cattle. The grain is fine and the yield fairly good.

XXV. *Sonahiri.* The colour of the husk of this rice is deep red, and it is obviously closely related to *Sada gulab* (*see* below), though later than the latter. It is an Upper Sind variety, which has a very light, thin, brittle grain. The plant tends to lodge badly.

XXVI. *Sada gulab.* This is a superior *sugdasi* variety in Upper Sind, with a rose coloured husk. The plants are tall and late in maturing. The grain is somewhat lighter than *Prong* and higher in quality than the latter but very brittle. It is not commonly grown.

XXVII. *Unnamed new type B.* This type, developed from a stray plant in Upper Sind, is a tall plant, late in ripening and has a long and heavy grain. The straw is strong. There is much sterility in the earheads. This is a scented variety.

XXVIII. *Unnamed new type C.* This is another type developed from a stray plant found in a field of *Prong* (Upper Sind). It has a fine white grain, but the yield is low.

XXIX. *Prong.* This is second only to *Kangni* in extent of cultivation in Upper Sind. It is tall, and matures much later than *Kangni*. The grain is long, thick and heavier than all the other *sugdasi* varieties. The straw is tough and not liked by cattle, and the grain is threshed with more difficulty than with other varieties.

XXX. *Bengalo.* This is a scented rice, better in quality even than *Jajai* (*see* below) but was obtained in Lower Sind. It ripens at the same time as *Jajai*, is a fairly high yielder and the grain is fine and white.

XXXI. *Motiaro.* This variety was obtained from Johi taluka in the south of the Larkana District, where it is much appreciated and fetches a good price. It is a low land variety, tall and matures late. The earhead is highly branched and well filled with coarse grains, looking like beads—hence its name.

XXXII. *Unnamed new type Z X.* This is a wild rice in Upper Sind, with a very luxuriant growth and a coarse red grain.

XXXIII. *Unnamed new type D.* This, again, was developed from a stray plant in a field of *Prong*, in Upper Sind. It has a coarse red grain and is a low yielder.

XXXIV. *Unnamed new type Z.* This is also a type from Upper Sind, with a very long, thick red grain. It ripens late, yields well, but the grain sheds badly.

XXXV. *Unnamed new type E.* Another wild rice from Upper Sind, dwarf in character; the leaves being very conspicuous with a dark margin. The grain is red and coarse with a black husk and black awns. The shedding is very great.

III. Characteristics of rice varieties in Sind.

It is proposed in the present section of this paper to consider the characteristics of a large number of the varieties of rice as above classified and described. Some of these characters are morphological, some are agronomic, and some physiological in character.

Morphological characters.

Awn characters of Sind rices. No feature is more variable among the rices grown in Sind than the awn character. Of the thirty-five Sind types collected, awns are

present on eleven varieties, most of which ripen late and all of which come from the drier conditions of Upper Sind. Where present, the awns have the same colour as the tip of the inner glumes. Most of the awned types have a generally vigorous growth, and the awns are valuable as a protection from pigs, birds, rats, and certain insects. They are associated with both fine and coarse rices, as the following table shows.

TABLE I.

Awn characters of Sind rices.

Variety	Awn character	Colour of		Character of rice
		Awn	Apiculus	
1. *Motiaro* . . .	Very long Coarse, Erect.	Coloured . .	Coloured . .	Coarse, high yielding.
2. New Type Z . .	Long . . .	Coloured when young.	Do. . .	Coarse.
3. New Type Z A. .	Medium Coarse Erect.	Do. . .	Do. . .	Coarse : Kernel red.
4. *Sonahiri* . .	Long . . .	Coloured . .	Do. . .	Fine scented rice.
5. *Sada Gulab* . .	Rather long . .	Do. . .	Do. . .	Do.
6. *Prong* . . .	Medium . .	Do. . .	Do. . .	Do.
7. *Bengalo* . . .	Do. . .	Do. . .	Do. . .	Do.
8. *Sighro* . . .	Do. . .	No colour . .	No colour . .	Do.
9. New Type B. . .	Do . .	Do . .	Do. . .	Fine : white grain.
10 New Type D. . .	Do . .	Do. . .	Do. .	Coarse red grain.
11. New Type C. . .	Do . .	Coloured . .	Coloured .	Fine rice : white grain.

Colour relationship in Sind rice plants. (*a*). *The leaf sheath.* The colour of the leaf sheath is a useful character for diagnosis, as it can be seen in the seedling stage. The normal colour varies from yellowish-green or green to a shade of red or purple; it may be temporary or permanent. The majority of the Sind rices have a green leaf sheath; only seven out of the thirty-five types studied have it coloured. All the varieties with a green leaf sheath have a white grain kernel. The converse is not, however, true.

It has been stated by Graham (2) that the colour of the leaf sheath in rice is associated with a similar colour of the apiculus. This association does not, however, exist in the Sind types. The following table shows the colour of various organs in seventeen varieties of Sind rices.

TABLE II.

Colour relationships in Sind rices.

Variety	Presence of Red Colour in			Colour of Inner glumes and paleae.	Colour of kernel
	Leaf sheath	Apiculus	Outer glumes		
1. *Kangni*	Present	Present	Absent	White	White
2. *Sathiya*	Do.	Absent	Do.	Do.	Do.
3. *Kunjro*	Do.	Do.	Do.	Do.	Do.
4. *Torh*	Do.	Do.	Do.	Do.	Do.
5 New Type G.	Do.	Present	Do.	Do.	Red.
6 *Sindhi Kambroo* . . .	Do.	Absent	Do.	Do.	Do.
7. New Type Y	Do.	Present	Do.	Do.	Do.
8. *Gan a*	Do.	Do.	Do.	Do.	Do.
9. *Motya*	Do.	Do.	Do.	Do	Do.
10 New Type Z a. . . .	Do.	Do.	Present	Do.	Do.
11. New Type E.	Do.	Do	Do.	Black	Do.
12. *Ratrya*	Absent	Do.	Do.	Red	White.
13. *Pista*	Do.	Do.	Do	Black	Do.
14. *Prong*	Do.	Do.	Do.	Yellow	Do.
15. *Sonahari*	Do.	Do.	Do.	Red	Do.
16 *Sada Gulab*	Do.	Do.	Do.	Do.	Do.
17. *Motiaro*	Do.	Do.	Do.	Yellow	Do.

(*b*). *Inner glumes*. The colour of the inner glumes (*paleae* and *lemma*) may be white, yellow, red or black, though each group includes many shades. The colours for each variety are constant and form a diagnostic character. It may be noted, too, that the prominence of the ridges and grooves on the surface of the inner glumes is characteristic of the varieties. They are usually prominent in coarse varieties and faint on slender rices.

(*c*). *Apiculus*. The apiculus or the tip of the inner glumes may or may not be coloured, and the colour may be temporary or permanent. Thus a distinctly coloured tip at the time of flowering has been noticed, where the colour fades as the plants approach maturity. On the other hand, some varieties show a green tip at flowering where colour developes as the grain matures. As already stated, the colour of the *apiculus* is *not* constantly associated among Sind rices with the colour of the leaf sheath or of the outer glumes.

Height of the main culm. The variation of the height of the main culm was only measured ***within*** each of the three main varieties studied, namely, *Kangni*, *Jajai*, and *Prong* when grown under similar conditions at one place (Larkana). The height

was measured from the ground to the tip of the topmost spikelet, and between 450 and 500 plants were examined in each case The mean height in these three varieties was as follows :—

	Inches.
Kangni	51·4±·14
Jajai	55·6±·42
Prong	51·7±·44

Generally, short varieties are low yielders, but when the height is greater than 42 inches, added height is not associated with heavier yield. High varieties are, in general, more liable to lodge. *Jajai* lodges badly and the types accustomed to submergence in water (*Lari* etc.) lodge still more seriously. Among the *sugdasi* varieties, *Prong* lodges less than the others.

Tillering capacity. As a rule, tillering in rice plants commences a fortnight after transplanting and continues for two or three weeks. Under deep water conditions, such as prevail in the rice swamps of the Lar tract, tillering is very largely prevented.

While the *relative* number of tillers is a character which is characteristic of varieties, and especially of strains of varieties, yet the amount of tillering varies in different years, probably owing to variations in the manner of water supply and the land on which they are grown. This is illustrated by the following figures for two pure strains of each of the varieties *Kangni*, *Jajai* and *Prong* at Larkana. The figures are based on the examination of 50 plants in 1924, 250 plants in 1925, and 500 plants in 1926.

TABLE III.

Number of tillers in plants of selected strains.

Variety and strain		Number of tillers per plant (mean)		
		1924	1925	1926
Kangni strain . . .	27 . .	11·6±·34	19·1±·25	9·6±·15
	13 . .	10·5±·28	17·8±·32	11·0±·17
Jajai strain . .	77 . .	10·5±·22	20·3±·38	11·7±·19
	43 . .	12·9±·23	21·2±·39	13·0±·17
Prong strain .	36 . .	13·7±·25	20·3±·37	14·5±·18
	51 . .	12·5±·27	17·4±·27	11·8±·15

So far as the varieties, as they occur in cultivation, are concerned, the tillering capacity is of course much more variable than the above, and the late varieties are, on the whole, distinctly more highly tillering than the early ones, though there are exceptions. The following tables show, for the early and late rices separately, the relative tillering capacity under similar conditions for three years. The figures for 1924 and 1925 are based usually on the examination of from 130 to 150 plants, and those for 1926 on 500 plants.

TABLE IV.

Number of tillers per plant in early varieties.

Variety	Mean number of tillers per plant		
	1924	1925	1926
1. *Kariaro*	9·4	..	—
2. *Barsati*	9·8	8·9	—
3. *Bengalo*	10·0	.	—
4. *Sighro*	10·7	12·9	—
5. *Sindhi Karbroo*	12·7	9·5	—
6. *Parsad*	13·0	..	—
7. *Chajrar*	13·2	11·3	—
8. *Kangni* (strain 14)	13·2	..	-
9. *Ganjro*	14·6	9·9	—
10. *Sathri*	14·7	9·8	-
11. *Badri*	1·50	11·0	—
12. New Type A.	15·2	9·7	—
13. *Motiaro*	15·8	13·8	—
14. *Red Kangro*	20·4	..	—
15. *Torh*	21·6	18·3	22·0

Taking these early rices it will be seen that *Torh* stands out as a high tillering rice in each year.

TABLE V.

Number of tillers per plant in late varieties.

Variety	Mean number of tillers per plant.		
	1924	1925	1926
1. *Ganja*	13·3	—	—
2. New Type Z a.	13·5	--	--
3. *Lari*	13·8	16·8	—
4. *Pista*	11 1	—	—
5. *Prong* (Strain 65)	16 0	16·5	—
6. *Sonahari*	16·1	10·1	--
7. *Sada Gulab*	16 9	11·1	--
8. *Kunjro*	17 0	17·9	—
9. New Type B.	19·4	—	—
10. *Jirashahi*	20 5	..	23·2
11. *Motya*	..	9 3	—

Taking the rices actually in cultivation, it will be seen that *Jirashahi*, and *Kunjro* stand out as giving a constantly high tillering capacity among these late Sind varieties.

In 1925, a large number of foreign varieties, brought either from other parts of India or from other rice growing countries, were grown under similar conditions to the types indicated above, and their tillering capacity determined. They were transplanted as single plants, 12 inches by 9 inches apart, on July 22, 1925. The tillering capacity of these varieties was as follows. The details are given in Appendix A.

(1) *Konkan rice varieties.* The strains of the Kolamba rice of the Konkan, isolated at Karjat, gave from 11·7 to 20·9 tillers per plant, corresponding closely to the late Sind varieties.

(2) *Bengal rice varieties.* Six varieties were tested from Bengal, and these gave from 9·6 to 31·7 tillers per plant. The high varieties were *Indrasail* with 30·6 and *Dadkani* with 31·7 tillers. The former of these is one of the very high yielding *aman* rices of Bengal.

(3) *Assam rice varieties.* In tillering capacity, the fifteen varieties of Assam rice were similar to the samples from Bengal, varying from 8·6 to 30·5 tillers per plant. The highest varieties are *Indrasail* with 29·1 tillers, *Tipidumia* with 30·3 tillers and *Negrasail* with 30·5 tillers per plant.

(4) *Central Provinces rice varieties.* None of the eight rices tested from the Central Provinces, except one had a high number of tillers per plant.

This one was a variety named *Khut bhara* which gave 25·6 tillers per plant.

(5) *Dacca deep water rice varieties.* These plants were not in their element as it was not possible to supply them with enough water, and hence they were somewhat sickly. Under these conditions none of the three varieties tested gave more than 16·0 tillers per plant.

(6) *Japan rice varieties.* Ten varieties from Japan were tested. All of these were dwarf types, and the tillering was delayed. No grain was produced in any of them though the spikelets were normal in appearance. Most of them gave very few tillers, six of them giving from 6 to 10 tillers per plant. The highest (*Oba*) only gave 16·6 tillers per plant.

Length of earhead and number of branches in panicle. The length of the earhead and the number of branches in the panicle was studied for twenty-six Sind varieties grown under similar conditions in 1923, measurements being taken (except in the new unnamed types) of between 100 and 200 heads in each case. The actual figures are given in Appendix II. There is, of course, nothing absolute about the figures though they are comparable among themselves. The length of the earhead in Sind types varied from seven to ten inches and the number of branches in the panicle from eight to eleven. The longest ear with the greatest number of panicle branches was possessed by the *Motiaro* variety, a bearded, medium ripening type from the Johi taluka of the Larkana District (*see* above). This gave in 1923 an earhead with an average length of 10·2 inches, and an average of 17·6 branches per panicle.

A much more detailed examination of these characters was undertaken with the three varieties (*Kangni, Jajai* and *Prong*) selected for special study. In 1922 over one thousand earheads were examined in each case, and in 1923 nearly five hundred.

TABLE VI.

Earhead characters of selected Sind rice varieties.

Variety		Number of ear heads examined	Mean length of earhead inches	Mean number of branches
1. *Kangni*	1922	1780	8·3	8·7
	1923	118	8·2	9·6
2. *Jajai*	1922	1100	11·6	9 6
	1923	479	11·1	9·2
3. *Prong*	1922	1100	11·6	9·8
	1923	480	10·2	8·9

These figures show the very large variations in the density of the earheads. *Kangni*, though having a short earhead contains an equal number of branches per panicle with the other two types examined.

Number of spikelets per earhead in Sind rices. Jacobsen (6) in a report on Philippine rices, shows that, grown under similar conditions the number of spikelts per earhead varies in that country from 50 to 178. The range in Sind does not seem quite so great, but in tests of twenty-five varieties in 1923, all grown together at Larkana, a range of 92 to 303 was found. The detailed figures are given in Appendix III. It will be seen that *Jirashahi*, a variety from Hyderabad, stands highest with 303 spikelets per earhead, but the grain of this variety is very small. It is also the case with the other varieties with a large number of grains per earhead, such as *Kunjro* (251 grains) *Pista* (206 grains) and *Motiaro* (196 grains). Some fine grained varieties from the Konkan and Bengal grown under similar conditions in the same season gave similar figures. Thus Kolumba No. 42 and Kolumba No. 79 from the Konkan gave 203 and 231 grains respectively per earhead. A fine Bengal rice gave 124 grains, and the *Dadkani* variety from Bengal gave 203 grains per earhead.

Weight of grains in Sind rices. Most of the Sind varieties of rice have large heavy grains. The rice growers are not familiar with the finer, lighter grain types; they have, in fact a prejudice against them, especially when they are not suitable for parboiling. As a rule, heavy grain varieties mill better than light ones.

The types may be classified into light (1·5 grams or less per 100 grains), medium (1·5 to 1·9 grams per 100 grains), heavy (2·0 to 2·5 grams per 100 grains), and very heavy (above 2·5 grams per 100 grains). Out of a large number of Sind types examined the results may be summarised as follows:

(1) *Light grained types. Kunjro, Jirashai, Dadkani* and *Pista*. Weight varied from 0·92 grams (*Kunjro*) to 1·13 grams (*Pista*), per 100 grains.

(2) *Medium grained types. Jajai, Motiaro, Sughro, Red Kangro, Sathri, Parsad, Bidri*. Weight varied from 1·84 (*Bidri*) to 2·1 (*Jajai*) grams per 100 grains.

(3) *Heavy grained types. Prong, Ganjro, Ratrya, Sonahiri, Torh, Kangni*, and *Sada Gulab*. The weight varied from 2·2 (*Sada Gulab*) to 2·4 (*Prong*) grams per 100 grains.

(4) *Very heavy grained types. Ganja* and *Lari*. The weight in these cases was 2·9 (*Ganja*) and 3·0 (*Lari*) grams per 100 grains.

To make clear the meaning of these figures it may be stated that Copeland (3), from Philippine experience, takes 2·0 grams per 100 grains as the grain weight of ordinary commercial rices. The fine rices of Western India and Bengal, however, are much smaller. Two strains of (Konkan rice *Kolamba*) from Karjat, grown in Sind, gave 1·3 and 1·0 grams per 100 grains respectively, and a Bengal rice gave 1·95 grams per 100 grains.

AGRONOMIC CHARACTERS.

Yielding capacity of Sind rices. In all questions of improving farm crops, the paramount importance of maintaining a high yield must always be fully recognised. The yield is, in the case of rice, obviously a complex of many factors, such as tillering power, number of grains per earhead, sterility percentage in the panicle, and a special difficulty in the study of the capacity to yield in the case of the various varieties is the very great variability from year to year. In spite of this difficulty, however, the results of several seasons show that high yielding types, on the whole, maintain their superiority from year to year. This is still more the case in selecting strains out of the different varieties. In the intensive study of the *Kangni*, *Jajai* and *Prong* varieties, it has been possible to isolate strains which for several years have consistently given high yield, and in which yielding power behaves as a hereditary character. These will be dealt with later. In the meantime, some idea of the position with regard to the plants of the Sind varieties, as grown side by side at Larkana, may be given.

In 1923, twenty-six distinct varieties of Sind rice were under trial, being planted in a similar manner in each case. Ten single plants of each were harvested separately and from these it was found that the average yield per plant varied from 19 to 58 grams. *Torh*, *Motiaro* and New-Type Y were found to be very heavy yielders. When the yield *per earhead* was taken, the same varieties stood at the top of the list. In 1924 and succeeding years a large number of plants (generally over 100) of each variety were examined, but in each year same varieties have maintained their position. Detailed results of the yield are given in Appendix IV, with those of a number of rices from other parts of India and from Japan, grown under similar conditions in 1925.

Period of growth in Sind rices. The time required by a variety of rice to come to maturity is a matter of very great importance, especially in a country where the time during which water is available is limited. The character of inundation season in Sind is very uncertain: when the season is shortened, the essential requirement of an efficient variety is speed of growth. Varieties which are late in ripening cannot always succeed and are hence useless. Of course, as would be expected, the length of the growth period varies a good deal with the area in which a particular variety is grown. Thus the Upper Sind variety *Prong*, which is late in its own area, matures much more quickly in Lower Sind. On the other hand, *Kangni*, the favourable early variety of the Larkana district has its period of growth increased in Lower Sind. The Lower Sind type *Ganja* was found to mature considerably later in Larkana than in its own area. Further a very early variety of rice from Ratnagiri (Konkan) was found to take a much longer time for ripening in Larkana. These variations are, of course, in accordance with what has been found elsewhere, and all comparisons of time required for growth have, in the present paper, been made on the basis of cultures on similar land at Larkana in Upper Sind.

In rice some varieties flower in a definite length of time, more or less irrespective of their date of sowing and transplanting: others flower, every year, at a particular time, no matter whether they are transplanted early or late. The former mode of flowering has been termed, 'periodically fixed' and the latter 'timely fixed' by Mitra (8). The following varieties of rice belong to the former class:—(1) *Kangni*, (2) *Sathri*, (3) *Ganjro*, (4) New Type A and this is shown by the records of 1923, 1924 and 1925.

TABLE VII.

Time of flowering of 'Periodically Fixed' types of rice.

Variety		Date of transplanting	Number of days transplanting to flowering
Kangni	1923	June 28, 1923	78
	1924	July 16, 1924	78
	1925	July 11, 1925	80
Sathri	1923	July 7, 1923	65
	1925	July 21, 1925	62
Ganjro	1923	July 8, 1923	55
	1925	July 21, 1925	51
New Type A.	1923	July 8, 1923	48
	1925	July 21, 1925	47

The 'timely fixed' varieties of rice in Sind seem much more numerous, and among these it will be found that the dates of flowering will be hardly affected by the date of transplanting. The following table shows this.

TABLE VIII.

Time of flowering of 'Timely Fixed' types of rice.

Variety		Date of transplanting	Date of flowering	Number of days transplanting to flowering
Sighro	1923	July 8, 1923	September 11, 1923	65
	1925	July 21, 1925	September 12, 1925	54
	1926	July 7, 1926	September 12, 1926	67
Bidri	1923	July 8, 1923	September 11, 1923	65
	1925	July 21, 1925	September 11, 1925	53

Time of flowering of 'Timely Fixed' types of rice—contd.

Variety		Date of transplanting	Date of flowering	Number of days transplanting to flowering
New Type B.	1924	July 23, 1924	October 2, 1924	71
	1925	July 7, 1925	October 3, 1925	88
Jirashahi	1924	July 23, 1924	October 24, 1924	93
	1925	July 12, 1925	October 22, 1925	102
Toh	1923	July 8, 1923	September 29, 1923	83
	1925	July 21, 1925	October 3, 1925	74
Jajai	1923	June 28, 1923	October 4, 1923	98
	1924	July 16, 1924	October 9, 1924	84
	1925	July 11, 1925	October 4, 1925	85
Prong	1923	June 28, 1923	October 10, 1923	105
	1924	July 16, 1924	October 17, 1924	94
	1925	July 11, 1925	October 8, 1925	90

In determining the earliness of varieties of rice, early flowering is usually considered as an index of early maturity. This is, however, not strictly true: for the interval between flowering and maturity has been found to vary considerably. In fact, among Sind varieties, the time from flowering to maturity varies from 24 to 53 days. The variation is much more limited than if varieties from other parts of India and abroad are included: a number of these grown at Larkana showed variation from ten to eighty days. Philippine varieties (Crisostomo 15) varied from eleven to sixty-nine days.

The interval between flowering and maturity varies from season to season not only with the same variety, but also with the same strain, of rice. In 1923, for instance, it was much shorter than in 1924 and 1925 at Larkana with selected strains from *Jajai* and *Prong* rices. The actual mean figures for four strains were as follows :—

TABLE IX.

Seasonal variation in the ripening period.

Strain		Number of days from flowering to maturity 1923	1924	1925
Jajai	No. 77	20·7	29·9	30·2
	No. 43	22·9	31·9	31·4
Prong	No. 36	27·7	34·2	30·7
	No. 51	28·7	32·0	32·1

In assigning values, therefore, in terms of days required to mature, the time of sowing and transplanting is very important with varieties whose flowering is 'timely fixed' though of less account with those whose flowering is 'periodically fixed.' Further, the variation from season to season must be kept in view. With these limitations, however, the figures obtained for the period from transplanting to flowering and for the total life period in 1925 and 1926 are of value. They at least show a similar relationship *between the varieties* in the two years.

TABLE X.

Flowering and ripening period of Sind varieties.

Variety	1925			1926		
	Days from transplanting to flowering	Days from transplanting to ripening	Days for ripening	Days from transplanting to flowering	Days from transplanting to ripening	Days for ripening
A. Early varieties—						
Red Kangro . . .	53	83	30	63	100	37
Sighro	54	88	34	61	100	39
Bidri	53	92	39	—	—	—
Ganjro	57	92	41	-	—	—
Barsati	59	97	38		-	—
New type A. . . .	47	100	53	-	—	—
Sathri	62	100	38	—	—	—
Sindhi Kambroo . .	8	101	43	—	—	-
Kangni No. 27 . . .	78	102	24	72	112	40
B. Medium varieties						
Toh	74	108	34	81	113	32
New type Y. . . .	69	108	39	77	115	38
Sada Gulab . . .	67	108	41	—	-	-
Sonahiri	67	108	41	—	—	—
Motiaro	81	110	29	86	125	39
Jajai	84	116	32	77	128	51
Chajrai	66	119	53	—	—	—
Bengalo	75	119	44	85	128	43
C. Late varieties—						
Ganja	71	121	50	—	—	—
Lari	72	121	49	—	—	—
Kunjro	84	121	37	—	—	—
Ratrya	82	123	41	—	—	—
Prong	93	126	33	88	131	43
Motya . . .	86	131	45	—	—	—

Corresponding figures for a number of foreign varieties as grown in Sind are given in Appendix V.

IV. Quality among Sind varieties of rice.

Quality in rice is related to a number of characters of the grain of which the chief are (1) the size and shape of the grain and kernel, (2) the colour of the kernel, (3) the hardness of the kernel, (4) the percentage of hull, (5) the flavour and cooking qualities. These will be dealt with in succession as applied to Sind rice.

1. *Size and shape of the grain and kernel.* In India rices are bought and sold on the character of the grain and a general preference is shown for rice which has a slender grain. All so-called coarse rices have a broad grain, and so slenderness is an essential for a rice to be counted as fine. As regards the length of the grain, opinions differ as to whether a long grain is to be preferred to a short grain, but the consensus of opinion is that a long slender grain is a finer rice, and so this commands a larger price in the market.

Graham (2) divides grains of rice into four classes :—

(1) Long spikelets, when the length is more than four times the breadth.
(2) Fine spikelets, when the length is more than three times the breadth.
(3) Coarse spikelets, when the length is more than twice the breadth.
(4) Round spikelets, when the length is less than the breadth.

Classified in this manner some of the Sind varieties stand as follows :—The figures indicate the length divided by the breadth.

(1) *Long rices, Dadkani*, (1·11), *Prong* 65 (4·10) *Sighro* (4·18), *Red Kangro* (4·12). A long Konkan rice (*Kolamba* 79) grown in Sind gave 1·21 as the proportion between length and breadth.

(2) *Fine rices, Bengalo* (1·02), *Sonahiri* (1·05), *Jirashahi* (3·86), *Chajrai* (3·83), *Parsad* (3·81), *Kangni* 11 (3·78), *Jajai* (3·71), *Barsati*, (3·60), *Bidri* (3·41), *Sathri* (3·38). A fine *Kolamba* rice (*Kolamba* 12) grown in Sind, gave 3·41 as the proportion between length and breadth.

(3) *Coarse rices Lari* (2·99), *Torh* (2·92), *Sindhi Kambroo* (2·81), *Motiaro* (2·69), *Pista* (2·43), *Kangro* (2·27).

Though the ratios just given indicate the fineness or coarseness of the rice, the actual length and breadth of the various types is a matter of some importance, and the following figures relating to the principal varieties are therefore interesting. They relate to the crops of 1925, but there is little change from year to year :

(*a*) *Long grained rice.* (These include those whose length of grain is above 8·9 mm.) New Type Z (10·2 mm.), *Sighro* (9·6 mm.), *Kangni 11* (9·4 mm.), *Sonahiri* (9·3 mm.), *Prong* 65 (9·2 mm.), *Lari* (9·1 mm.), *Barasati* (9·0 mm), *Bengalo* (9·0 mm.)

(*b*) *Rices with grains of medium length.* (These include those whose length of grain lies between 7·9 and 8·9 mm.) *Chajrai* (8·9 mm.), *Sindhi Kambroo*

(8·8 mm.), *Ganja* (8·7 mm.), *Jajai* 63 (8·6 mm.), *Bidri* (8·5 mm.), *Parsad* (8·4 mm.), *Red Kangro* (8·2 mm.), *Sathri* (8·1 mm.).

(c) *Rices with short grains.* (These include those whose length is below 7·9 mm.) *Dadkani* (7·8 mm.), *Motiaro* (7·5 mm.), *Jirashahi* (6·9 mm.) *Pista* (5·6 mm.), *Kanjro* (5·4 mm.).

With regard to breadth of grain, the varieties may be classified as follows. The measurement refers to the position of the grain as it lies in the table, and represents the maximum breadth.

(a) *Rices with slender grains.* (These include those with a grain breadth of less than 2 mm.) *Jirashahi* (1·8 mm.).

(b) *Rices with oval grains.* (These include those with a grain breadth of 2 to 2·5 mm.) *Bidri, Kangro, Sighro, Jajai, Barsati, Sathri, Sonahiri Chajrai, Parsad, Kangni, Prong, Pista, Bengalo, Red Kangro.*

(c) *Rices with flat grains.* (These include those with a grain breadth of more than 2·5 mm.) *Ganja, Sindhi Kambroo, Lari, Motiaro, Ganjro, Torh.*

It will be noticed from the above, and the description of the varieties given on page 118 that nearly all the commercial varieties of Upper Sind, including *Kangni*, the *Sugdasi* varieties and *Sathri* are oval grained and hence highly valued for quality on the market. The Lower Sind varieties are mostly flat grained, and hence are valued lower. Exceptions are the *Torh*, and *Motiaro* varieties in Upper Sind which are flat grained, but are grown for their high yield. Slender rices are practically unknown in Sind, and have little or no market.

Size of kernel. The size of the kernel that is to say, of the grain after shelling has been usually considered to correspond approximately with the size of the grain Graham (2) Copeland (3). This does not apply in the case of a number of Sind rices owing to very considerable variation in the thickness of the husk. The following figures for pure lines of three varieties of Upper Sind rice show this clearly.

TABLE XI.

Grain and kernel measurements.

Variety and strain.	Mean length of		Mean breadth of		Ratio, to Length Breadth	
	Grain	Kernel	Grain	Kernel	Grain	Kernel
	mm.	mm.	mm.	mm.		
Kangni 43 . . .	8·9	6·3	2·4	2·0	3·7	3·1
Jajai 43	8·0	5·9	2·3	1·8	3·5	3·3
Prong 36	9·4	7·2	2·4	2·0	3·9	3·5

2. *Colour of the kernel.* The kernel colour of rice may be red or white, though the white rices really vary from pale yellowish white to deep yellow. In-as much as

the world's commerce demands white rice, other things being equal, white rice is always preferred even in India. Out of the thirty-five Sind varieties described, only ten have red grains, namely *Ganja, Lari, Motya, Sindhi Kamroo* and six new types obtained as stray plants in the crop. The red grained rices are, in fact, usually very coarse and are often found as weeds in cultivated rices. They greatly lower the value of white rice by their presence. The variety *Motya* is, however, very well suited for parboiling. The red colour is superficial in all the Sind rices, and can be removed by proper milling.

3. *Hardness of the kernel.* Rice is described as hard or soft according to the appearance of the cut surface of a grain cut across the middle. Grains with a shiny translucent surface are termed hard; those with a dull white appearance are soft. The former mill better and stand shipment better than the latter, and while the latter tend to form a sticky mass when cooked, the former retain each kernel separate. The hard types are therefore considered to be of much higher quality.

The rice varieties of Sind may be classified in respect to this character as follows :-

(1) *Entirely hard* All *sugdasi* varieties, *Parsad, Red Kangro, Barsati, Pista, Jirashahi, Bengalo.*

(2) *Partially hard—Kangni, Torh, Motiaro, Ratrya, Kanjro, Chajrai, Sighro, Bidri.*

(3) *Soft or opaque Lari, Ganja, Sindhi Kambroo, Ganjro, Sathri.*

4. *Percentage of husk on the rice grain.* The proportion of husk may vary with different varieties grown under similar conditions from little over 18 to over 22 per cent. The light shelled varieties, giving from 18 to 19·5 per cent. of husk at Larkana in 1925, are *Sathri, Kangni, Ratrya, Prong, Motiaro* and *Sighro.* Medium shelled types with between 20 and 21 per cent. of husk are *Red Kangro, Sonahiri, Sada Gulab, Ganjro, Bidri* and *Jajai.* The heavy shelled types, with over 21 per cent. of husk, are *Dadkani, Parsad, Ganja, Jirashahi, Torh, Pista, Kanjro* and *Lari.* It may be noted that the Konkan *Kolamba* rices grown at Larkana classed as medium shelled types.

Flat and slender rices appear usually to be heavy shelled.

5. *Flavour and cooking qualities.* The so called "*Sugdasi*" varieties of rice in Sind derive their name from the presence of flavour and aroma in the grain and in the plant, "*Sugand*" meaning flavour in Sindhi. Graham describes this fragrance as a mouse-like smell possessed by the grain and also noticed when the rice is in flower in the field. It is usually not appreciated by Europeans, but is held in high esteem throughout India. The *Jajai* variety is the typical *Sugdasi* rice, but even among types of this variety there is a difference in this respect, for the type known as "*Ghogharo*" grown in the village of that name, is said to be better in this respect than any other, and to lose a portion of its fragrance if grown elsewhere. No careful tests on this point have, however, as yet been made.

In addition to their flavour and aroma, the *sugdasi* varieties have good cooking qualities, as, for instance, they are said to swell up on boiling to an extent that no other rice does. They are also reputed to need less *ghi* (clarified butter) in cooking than the coarser types.

The best known *sugdasi* rices are *Jajai* and *Prong* of Northern Sind, but the following varieties are also considered to come within the *sugdasi* group, *Sonahiri*, *Sada Gulab,* New Type A, and *Bengalo.*

V. Flowering and pollination among Sind rices.

The process of opening the flower and pollination shows considerable variation in different places. In Italy, Farnetti (18) reports that the flowers are almost always cleistogamous and the glumes remain closed throughout. Elsewhere three cases have been described, namely, the dehiscence of the anthers (1) before the opening of the glumes (2) at the same time as the opening of the glumes and (3) after they have emerged and are in a pendent position. The first two cases ensure self-fertilisation : the last makes cross-fertilisation possible : all the cases occur among Sind rices, though the proportion in which each occurs varies a good deal with different varieties. For example, in the *Motiaro* variety as grown at Larkana nearly half the number of spikelets were cleistogamous.

As regards the opening of the flowers in the various parts of the earhead in Sind, the flowers at the tip of the inflorescence are usually the first to open, and the opening continues in regular downward succession. This forms the general rule, but in some cases, flowers in the middle of the ear open first and opening continues both upward and downward.

A close study has been made of the opening of the flowers on single earheads in a large number of varieties of rice in two seasons, and embraces the observation of the period (number of days required for the opening of all the flowers on the earhead) and also of the time of day when the opening took place. Full details of these observations with ten varieties in 1922, and of twenty-three varieties in 1924, are given in Appendix VI. The general conclusions may be summarized here.

1. As grown at Larkana all varieties open their flowers early in the morning, and the process closes shortly after midday. The actual process of flowering in ten varieties taken together in 1922 is shown in the following figures from 1,250 flowers examined.

	No.	Per cent.
Flowers opened before 7-30 a.m.	nil	
,, ,, 7-30 to 8-30 a.m.	3	0·24
,, ,, 8-30 to 9-30 a.m.	53	4·24
,, ,, 9-30 to 10-30 a.m.	399	31·92
,, ,, 10-30 to 11-30 a.m.	626	50·08
,, ,, 11-30 a.m. to 12-30 p.m.	141	11·28
Flowers did not open	28	2·24
TOTAL	1,250	

Sugdasi rice varieties of Upper Sind

Similar figures for 23 varieties in 1924 gave figures as follows :—

	No.	Per cent.
Flowers opened before 7-30 a.m.	81	2·5
" " 7-30 to 8-30 a.m.	118	3·7
" " 8-30 to 9-30 a.m.	210	6·6
" " 9-30 to 10-30 a.m.	332	10·0
" " 10-30 to 11-30 a.m.	689	21·5
" " 11-30 a.m. to 12-30 p.m.	902	27·8
" " 12-30 to 1-30 p.m.	508	15·9
" " 1-30 to 2-30 p.m.	180	5·6
Flowers did not open	130	4·1
Abnormal spikelets	25	0·8
Rudimentary spikelets	8	0·3
Cleistogamous spikelets	43	1·3
TOTAL	3,226	

The actual range of time varies a little, as would be expected, from season to season, according to the climatic conditions of the season, and the different varieties vary much among themselves. Thus in the *Parsad* variety the bulk of the opening took place in 1924 before 8-30 a.m. On the other hand, in the *Ganjro* variety there was hardly any opening of the flowers before 10-30 a.m. The time of flowering for the whole of the varieties studied in 1922 and 1924 is shown in the graph in Figure 2.

2. The time of the day at which the rice plant flowers is partly determined by the date at which flowering takes place. The early varieties start flowering earlier in the morning than the later ones. Thirteen varieties studied in 1924 which flowered between September 8 and October 7 all began flowering at 7-30 a.m. Six varieties, whose flowering took place in the following month (8th to 23rd October) commenced opening the flowers not before 8-30 a.m. The four late types (whose flowering occurred between October 29th and November 9th) only began to open their flowers at 9-30 a.m. This difference was not purely a matter of temperature, as the opening of flowers commenced at a different temperature with the different varieties. The following figures show this :—

Variety	Date of flowering	Hour when flowering began	Air temperature
Parsad	September 14, 1924	7-30 a.m.	84°F.
Dadkani	October 17, 1924	8-30 a.m.	71°F.
Kunjro	October 29, 1924	8-30 a.m.	65°F.
Jirashahi	November 3, 1924	9-30 a.m.	70°F.

No flowers have been observed to open before daylight.

The closing of the flowering on each day again varies with the variety, but is earlier in the case of the early varieties than with the later ones. In no case does flowering continue after 2-30 p.m.

3. The flowering of a single earhead at Larkana continues for a period of from five to eleven days. The actual period observed for ten varieties in 1922 was from five to seven days, and for twenty-three varieties in 1924 was from five to eleven days. The progress of flowering during this period is shown in Figure 3. These figures may be compared with those noted by Thompstone and Sawyer (20) in Burma where the period of flowering ranged from seven to ten days.

The maximum flowering activity is reached in the second and third days of this period. There does not seem to be any relationship between the earliness or lateness of flowering and the number of days during which flowering continues.

4. The actual course of the opening of a flower is similar in Sind to that which has been described elsewhere. The glumes open very gradually and when the limit of divergence has been reached, convergence commences at once, until the act of closing is complete within about an hour, the time varying from 32 to 70 minutes.

VI. Sterility.

It would seem that the rices grown in all countries have a certain proportion of the spikelets in almost every head which never fill, and which, in fact, are sterile. But, in certain seasons, with the same varieties, the number of spikelets which does not produce grain increases very considerably and becomes what is usually considered by the people as a veritable disease. This is termed *Khas* in Sind and the term is applied to any condition in which the grain fails to an abnormal extent to set or to mature; wholly sterile heads are rare in Sind even in a year when *khas* is prevalent. The corresponding condition is known as *brusone* in Italy, *falla* in Spain, *imotsi* in Japan, *tiem* or *tim* in Cochin China, *gwabo* in Burma and perhaps as *mentek* in Java.

It is obvious that this term includes sterility due to a number of different causes. For instance, in every variety studied during the last three seasons, there are always some spikelets of the earhead, which do not reach full growth. These are, as a rule, situated in the lower part of the earhead. They dry up quickly and drop two to three days after emergence. These may be termed "*rudimentary*" spikelets.

Some of the spikelets, however, reach full size, but are incomplete,—one or both the reproductive organs being either absent or undeveloped. In many cases the anthers are shrivelled. They look distinctly white and remain on the ear during the green stage, but ultimately shrivel up and drop. These will be referred to as "*abnormal*" spikelets.

The remaining spikelets are at first apparently normal, and possess fully developed flower parts. As flowering proceeds, however, some of them fail to open their glumes and do not set grain. They may be called "*cleistogamic*" spikelets; others

Time of the day when opening of flowers takes place.

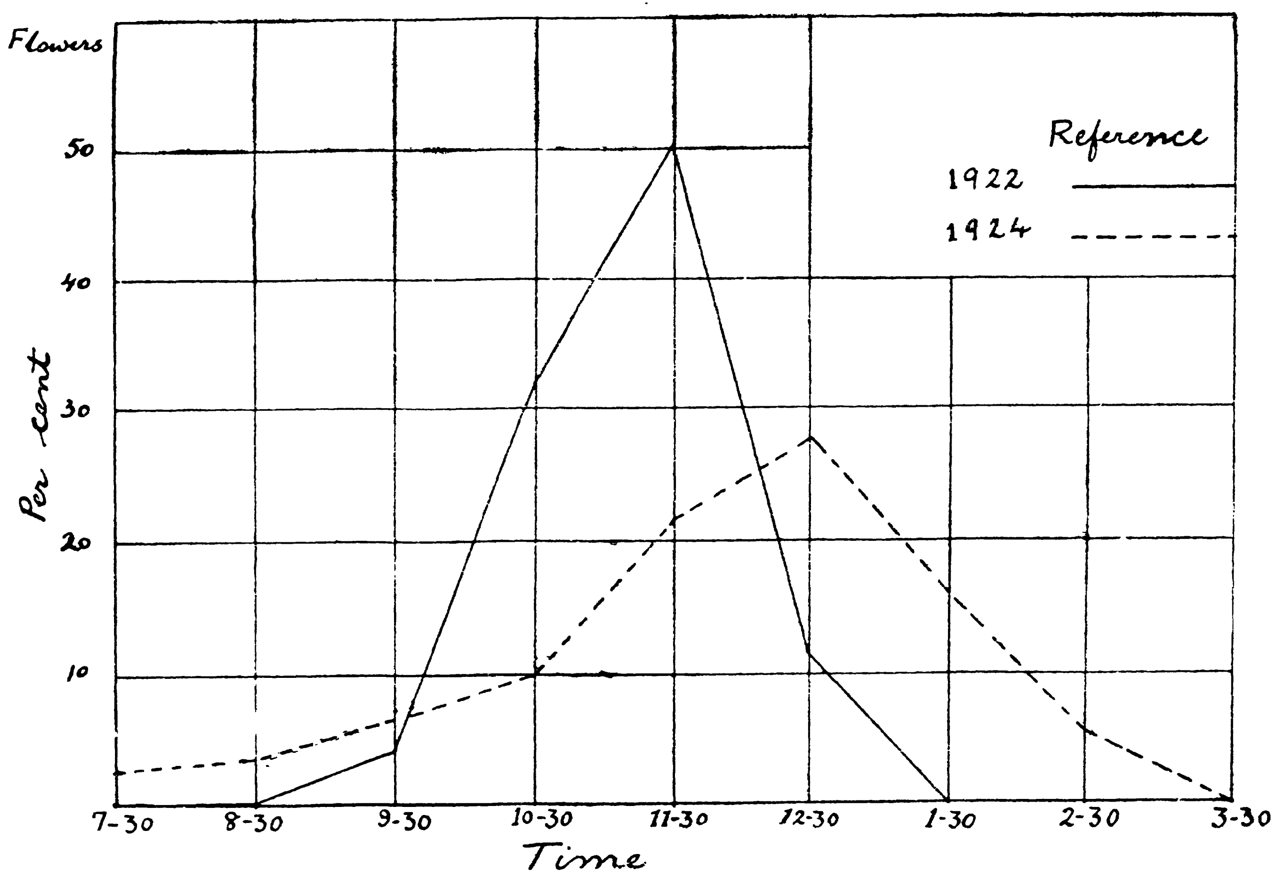


Fig. 2.

Period of flowering of a single earhead.

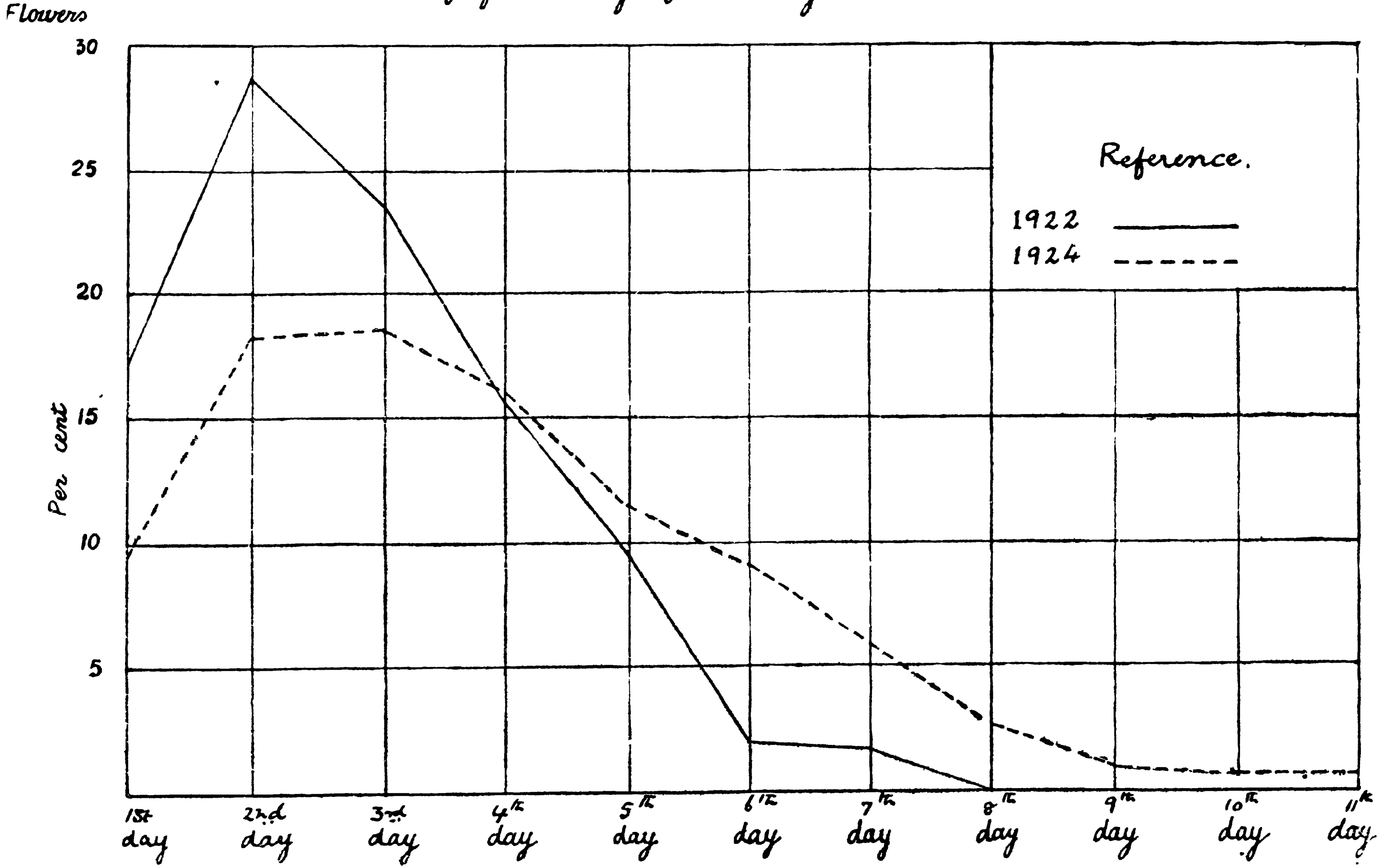


Fig. 3.

open their glumes and are fertilised, but fail to set or mature grain. These are the chief factors in sterility in the earhead and may be called "*aborted*" spikelets.

The relative importance of these types of sterility in a normal season may be indicated by the number found in ten earheads of the *Kangni* variety in 1925. These were as follows :—

Type of sterile spikelets	Number in 10 ears	Mean number per earhead	Proportion of total spikelets
			Per cent.
"Rudimentary" spikelets . . .	118	11·9	5·8
"Abnormal" spikelets	32	3·2	1·7
"Cleistogamic" spikelets . . .	96	9 6	4·8
"Aborted" spikelets	215	21·5	10·6
Fertile spikelets	1559	155 9	77·1

"*Rudimentary*" and "*Abnormal*" spikelets are only noted in the field and they soon drop. Counts taken for sterility in the laboratory, therefore, exclude these.

In 1924, a similar series of counts taken in the field with ten earheads of each of twenty-three varieties, gave the following mean figures.

	Per cent.
1. "Rudimentary" spikelets	0·2
2. "Abnormal" spikelets	0·8
3. "Cleistogamic" spikelets.	4·8
4. "Aborted" spikelets	18·5
5. Fertile spikelets	75·7

From these figures it will be seen that aborted spikelets are the chief source of the sterility observed in the field. These spikelets are found to contain undeveloped grain; many of them contain double grains both of which are shrivelled.

The number of sterile grains found after harvest in the various Sind varieties grown side by side at Larkana in 1923 and 1924 has been determined. This excludes, of course, the "rudimentary" and "abnormal" spikelets referred to above, as these can only be determined during the growth of the plants. The figures given

below, however, indicate the proportion of the total spikelets remaining on the head after harvest which do not contain grain.

I. Varieties with low sterility percentage.

	1923	1924
	Per cent.	Per cent.
Parsad	5·8	did not mature.
Torh	6·8	4·2
Dadkani	8·0	..
Kangani	9·7	6·2
Pista	6·6	did not mature
Motiaro	7·0	4·7
Sada Gulab	8·6	..
Kolamba Strain 79	10·1	7·8

II. Varieties with medium sterility percentage.

	1923	1924
	Per cent.	Per cent.
Sighro	11·1	18·8
Jajai	12·9	19·6
Kangro	13·3	17·6
Bidri	14·3	19·0
Sonahari	17·0	20·8
Red Kangro	11·8	15·0
Prong	13·6	15·5
Kolumba Strain 12	14·2	16·2
Ganjro	15·3	18·0
Sathri	17·1	24·3

III. *Varieties with high sterility percentage.*

	1923	1924
	Per cent.	Per cent.
Ratiya	22·7	..
Tari	30·3	26·9
Ganja	34·1	25·4
Jinashahi	30·0	Did not mature.

It will be noted that sterility seems to be a varietal characteristic, but that, particularly with the varieties of medium sterility, the difference from year to year is very great. This is illustrated by the more long continued observations on collections of reaped earheads after harvest of the three varieties which have been specially studied, namely, *Kangni*, *Jajai* and *Prong*. These have the following percentages in five successive years, the figures given being the mean of all strains.

Sterility percentage.

—	*Kangni*	*Jajai*	*Prong*
	Per cent.	Per cent.	Per cent.
1921	15·9	25·7	20·4
1922	9·1	17·3	12·1
1923	9·7	12·9	13·6
1924	13·4	21·6	15·8
1925	16·7	17·1	20·8
1926	11·1	20·3	23·1
AVERAGE	12·6	19·6	17·6

The cause of these large variations is not yet clear, yet it may be noted that the inundation, and hence the watering, in 1922 and 1923 was favourable, and in these years the sterility was low. The year 1921 was one of heavy inundation. In 1924 and 1926 the supply of water was late, but it lasted to the end of the season. The year 1925 was the most unfavourable of the series, for the inundation was not only late but only lasted for a very limited time. Much of the crop in the District was a failure.

In selected pure strains from the above three varieties (*Kangni*, *Jajai*, and *Prong*) there was found to be a considerable difference in percentage of sterility, most marked, however in years of high sterility. The following figures illustrate this :--

Variety and strain		Sterility percentage			
		1923	1924	1925	1926
Kangni	No. 27	8·7	12·5	20·9	10·1
	No. 43	9·2	9·8	12·6	12·1
Jajai	No. 77	8·3	21·2	19·1	19·3
	No. 43	9·6	21·6	15·2	21·2
Prong	No. 36	6·9	16·2	19·9	23 0
	No. 57	10·0	12·7	21·7	23·2

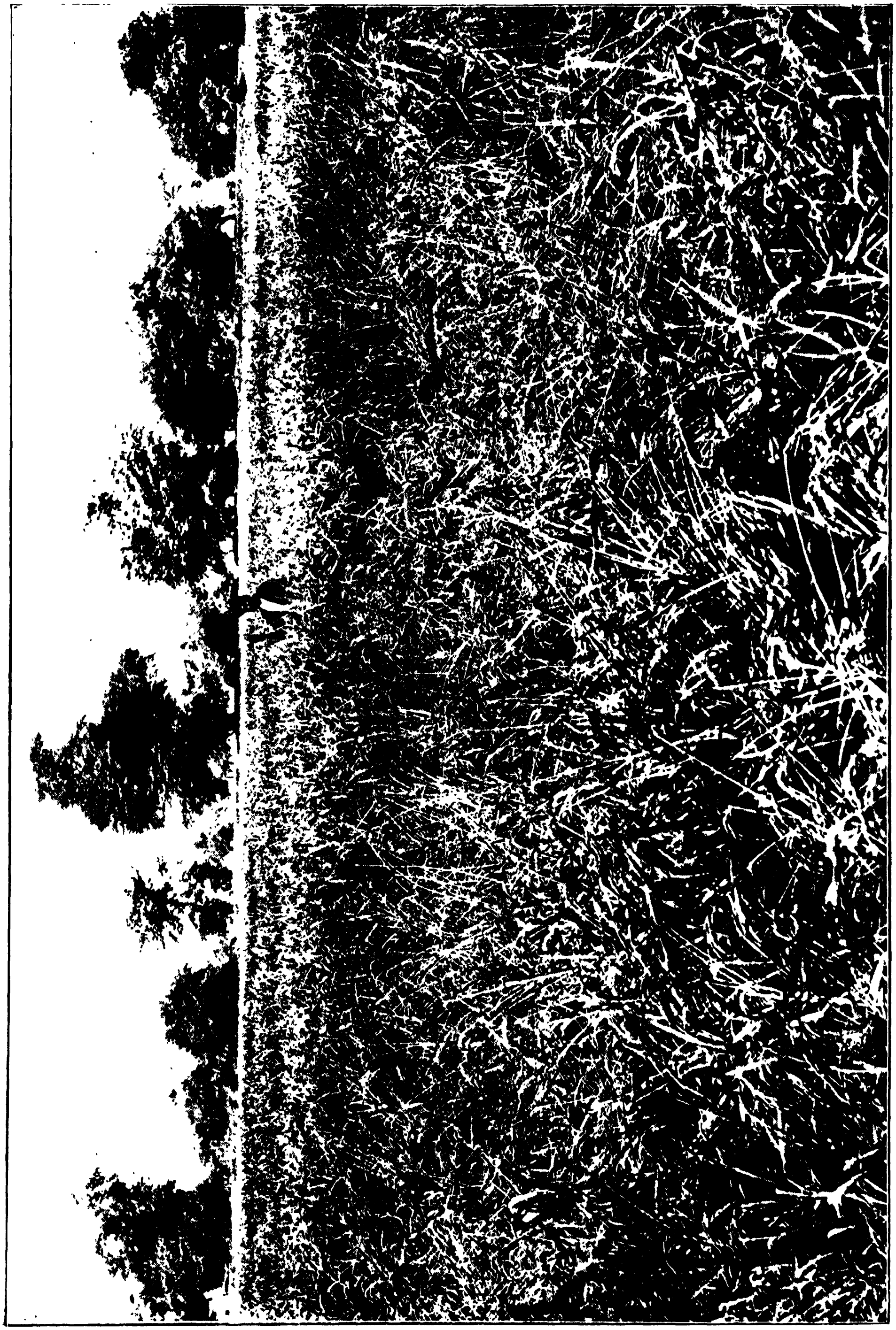
All attempts so far have not enabled these differences between varieties, or between the same variety in different years, to be connected with either insect or fungus attack. Further investigation in this direction is proceeding, but, in the meantime, the evidence regarding possible correlation between the amount of sterility and weather, water or soil conditions may be considered.

Effect of weather conditions. The records of the past eleven years show that excessive sterility (*khas*) has been complained of at Larkana in six seasons, and these seasons were all years in which westerly winds occurred at the time of flowering of the late varieties. For instance, in 1924 these winds occurred when the *Jajai* variety was in full bloom. On examination of the stigmatic surfaces in this variety they appeared very dry, and after excessive sterility was first noticed, this condition increased in a marked degree.

The forenoon temperatures during the flowering hours seem to have some effect on the setting of grain. Thus the morning temperatures in September in the year 1924 were much lower than in the preceding two years, and the sterility was also much greater in that year. It may be noted here that in Italy, where *brusone* or sterility is a serious matter, Averna-Sacca (19) has found evidence that it is primarily due to sudden and repeated changes of temperature.

Effect of water conditions. Late varieties for which the water partially fails in the latter part of the season show a very high percentage of sterility. For instance the *Jirashahi* variety in a favourable inundation season, showed a sterility percentage (determined on the dried earheads) of 30 : in a year when the late water failed, it gave a sterility percentage of 85. Similarly a late variety from Bengal gave 25 per cent. and 57 per cent. of sterility respectively under conditions of normal watering

PLATE III.



Plot of *Kangni* Rice No. 27, Larkana, 1925.

and failure of the late watering. Under the latter conditions, the dryness of the stigmatic surface is very marked.

In years of very high floods, sterility has also been found to be considerable. Under very moist atmospheric conditions, it has been noticed that the pollen grains are liable to burst prematurely, and this may, in part, be the cause of the effect noticed in years of high flooding.

Effect of soil conditions. In highly manured soils, it is well known that rice may not flower, but simply form excessive vegetative growth. In one instance, it was noticed in addition that the few earheads formed under these conditions had a high percentage of sterility. On the other hand, in very poor soils where the growth is stunted and the earheads small, the percentage of sterility is high.

Effect of other conditions. Earheads which are covered with muslin bags, in breeding work, always have a much larger percentage of sterility than earheads formed in the open in the same plot. Thus in three selected varieties, the following figures were obtained from a consideration of over five hundred heads in each case.

Sterility.

—	In open earheads per cent.	In covered earheads per cent.	Increase due to covering per cent.
Kangni	7·5	25 4	17 9
Jajai	12 8	44 0	31 2
Prong	14·4	63·5	49·1

This will, in a small measure, probably be due to the prevention of cross-fertilisation, but it is obvious that other causes are at work which have not yet been entirely ascertained.

VII. Selection and breeding in Sind rices.

Work on improvement of Sind rices has now continued since the year 1922. It was necessary in the first instance to obtain pure strains of several of the most valuable and widely used varieties and for this purpose attention has been concentrated on three of them. These are :—

(*a*) *Kangni.* An early prolific variety, giving a grain of medium, rather coarse quality, which is suited for cultivation on high lands, and which is used for export after parboiling. The bulk of the crop in the Larkana District is of this type.

(*b*) *Jajai.* A variety later than *Kangni*, but still moderately early. It is not prolific, but has fine and scented grain. It needs good soil on a fairly high level.

(c) *Prong.* A late prolific, variety, giving a fine and scented grain, not however equal to *Jajai* in quality. It requires low lying soil.

The actual technique adopted in the work to be recorded was as follows : –

(1) *Nursery.* A fortnight before transplanting, the seed is sown in seed beds ten feet square which are either, manured with sulphate of ammonia, or treated by the "*rab*" method. The seeds are sown in rows, placed one inch apart each way, using a perforated cardboard for the purpose. The seeds are not buried, but merely covered with ashes. Water is applied with a spray till the seedlings have rooted themselves, after which irrigation water is allowed to flow into the beds.

(2) *Transplanting.* This is best done in June, but when the river inundation is late it may be delayed by a month or even more. Single seedlings are transplanted nine inches apart in rows, which are themselves twelve inches apart. This spacing has been found enough for normal development and gives room for working without injury to the plants. The rows as a rule, run at right angles to the water channels, and are about one hundred feet long. The border rows are rejected in any determination of the yield. The plots used are usually one fortieth of an acre and are replicated several times.

When three replications are taken, the probable error in the yield of selected strains of each of the three varieties studied was as follows in 1923 :

Kangni. From 3·1 to 12·3 per cent. Mean 6·2 per cent.
Jajai. From 1·8 to 9·0 per cent. Mean 5·8 per cent.
Prong. From 5·0 to 14·2 per cent. Mean 8·0 per cent.

In 1924, seven or eight replications were taken of each strain and then the probable error of the yield figures was as follows :- -

Kangni. From 2·4 to 3·4 per cent. Mean 2·9 per cent.
Jajai. From 0·7 to 3·1 per cent. Mean 2·2 per cent.
Prong. From 1·9 to 4·5 per cent. Mean 3·5 per cent.

The extent to which selection can profitably be applied to maintain valuable characteristics of a plant is determined by the extent to which the characteristics result from innate and hence hereditary, causes, and to what extent they are modified or determined by the environment. It is first necessary, therefore, to take the seed of each pure strain, or at any rate of one pure strain in each variety, and see how the characters vary from plant to plant in pedigree culture. This has been done, in 1925-26, for one strain of *kangni* (No 27), one of the *Jajai* (No. 77), and one of *Prong* (No. 36) and the following tables show the variation which occurs, under these circumstances, in the several characters.

Table XII.

Statistical constants for Kangni rice, Strain 27.

Characters	Mean value	Modal value	Coefficient of variation per cent.
1. Days up to flowering	78·6 days	78—79 days	2·61
2. Days up to ripening	101·7 days	101—102 days	1·39
3. Length of 20 husked grains	13·7 cm.	13·8 —14·0 cm.	3·47
4. Breadth of 20 husked grains	4·5 cm.	4·5 — 4·7 cm.	5·30
5. Number of grains per gram of paddy . .	41·1	40·0 43·9	4·60
6. Percentage of husk in paddy	19·8 per cent.	18·1 —21·0 per cent.	15·60
7. Number of spikelets per earhead	146·3	119— 139	17·10
8. Number of fertile spikelets per earhead . .	115·4	101—120	19·4
9. Percentage of sterile spikelets per earhead. .	20·9	20 30	16·1
10. Number of tillers per plant (paddy) .	19·4	16 —22	32·2
11. Yield (paddy) of single plant in grams . .	41·0 grm.	35 - 45	37·9

Table XIII.

Statistical constants for Jajai rice, Strain 77.

Characters	Mean value	Modal value	Coefficient of variation per cent.
1. Days up to flowering	85·1	84—87	2·3
2. Days up to ripening	116·2	115—116	1·3
3. Length of 20 husked grains in centimetre. .	12·9	12·6 -12·8	4·3
4. Breadth of 20 husked grains in centimetre. .	41	3·9 - 4·1	8·3
5. Number of grains per gram of paddy . .	50	46 50	5·5
6. Percentage of husk in paddy	19·2	17 20	20·9
7. Number of spikelets per earhead	147·4	122 155	21·8
8. Number of fertile spikelets per earhead . .	114·8	97 134	31·5
9. Percentage of sterile spikelets per earhead . .	21·1	3·1 25·2	59·3
10. Number of tillers per plant	20·3	18 -25	43·9
11. Yield (Paddy) of single plant in grams . .	38·6	33 —41	44·6

TABLE XIV.

Statistical constants for Prong rice, Strain 36.

Characters	Mean value	Modal value	Coefficient of variation per cent.
1. Days up to flowering	91·4	89—94	3·16
2. Days up to ripening	122·1	121—123	2·10
3. Length of 20 husked grains in cm. . . .	14·3	14·5—14·7	2·7
4. Breadth of 20 husked grains in cm. . . .	4·2	4·2	3·8
5. Number of grains per gram of paddy . .	40·3	39—43	7·4
6. Percentage of husk in paddy	20·4	19—22	19·1
7. Number of spikelets per earhead . . .	109·6	111—136	28·3
8. Number of fertile spikelets per earhead .	89·2	72—97	27·9
9. Percentage of sterile spikelets per earhead .	19·9	10—20	58·7
10. Number of tillers per plant	20·1	19—26	13·2
11. Yield of single plant in grm.	36·1	28—38	16·4

The results obtained in each of the pure strains examined, though belonging to three different varieties, indicate that the period of growth, size of grain and weight of grain are fairly constant when the plants are grown together. The other characters are subject to very great variation, and depend very much on the particular environment of each plant.

But apart from these variations between plants of the same strain in pedigree culture, it has long been evident that each variety consists of a large number of strains of very different value. Attention was called to apparent changes in the character of the crop grown on the same field by Ishaq (11) and his observations can be easily explained by the originally mixed character of the variety which has been evident throughout the present investigation. In 1921 before the writer took over the control of these investigations one hundred heads had been selected in each of the three varieties under study, and these were grown in line culture in 1922. A number of the lines so obtained were rejected as weak or late, and the rest were harvested. The yielding capacity of the strains varied greatly, and the thirty

best yielders were kept for the further trial. The actual variation in yield per plant in each variety was as follows :—

TABLE XV.

Variation of yield in strains of rice varieties.

Variety	Number of strains	Highest and lowest yield per plant	Average yield per plant
		grm.	grm.
Kangni	89	1·4 to 5·1	2·4
Jajai	61	1·3 to 4·5	2·0
Prong	88	1·4 to 5·9	2·8

In the following year the thirty selected strains were sorted out, and finally only five of the strains of each variety were kept for study and multiplication. These were found to retain their high yielding character from generation to generation, but were still further reduced for convenience of multiplication in 1925 to three strains of *Kangni* (Nos. 27, 43 and 25), two strains of *Jajai* (Nos. 77 and 43) and two strains of *Prong* (Nos. 36 and 57). Tested in six or seven replications in that year (1925) and compared with the crop from unselected seed of the same variety, the following results were obtained.

TABLE XVI.

Increase of yield in selected strains of rice.

Variety	strain	Increased yield over unselected seed	Remarks
		Per cent.	
Kangni . . .	No. 27	19·1	All replications (6) agreed.
	No. 43	28·2	„ „ (7) „
	No. 25	31·7	„ „ (6) „
Jajai	No. 77	14·0	Six out of seven replications agreed.
	No. 43	27·4	Five out of seven replications agreed.
Prong	No. 36	32·2	All replications (6) agreed.
	No. 51	21·9	„ „ (7) „

The actual yields per acre obtained from these strains in three successive years in field scale trials may be of interest.

TABLE XVII.

Yield of selected strains of rice per acre.

—		1924	1925	1926	Maximum
		lb.	lb.	lb.	lb.
Kangni	No. 27	1,200	1,483	1,370	2,422
	No. 43	1,672	1,488	1,406	1,622
Jajai	No. 77	1,526	1,421	1,285	1,660
	No. 43	..	1,618	1,703	1,976
Prong	No. 36	1,288	1,575	1,406	1,628
	No. 51	1,320	1,320	1,012	1,320

The strains described have retained their special yielding character when grown on a large scale by farmers, and they are now established in cultivation.

The selected strains of each variety, having been selected for yield, do not show any large difference in time of ripening among themselves.

VIII. Acclimatisation of exotic rices.

While all the effects at improvement of rices for cultivation in Sind have concentrated on selection from the best of the local types, and especially on those suitable for cultivation in Upper Sind, the possibility of obtaining from abroad or from the other parts of India types of rice which could replace some of those now grown has not been neglected. In the course of this inquiry, an apparently indigenous type of rice, named *Bengalo* was discovered in cultivation, whose name proclaims its ultimate derivation from Bengal which is of some interest in this connection, as showing how some, at least of exotic rices, have already acclimatised themselves.

This *Bengalo* rice was found in cultivation at Tando Ghulam Hyder in Lower Sind, and proved to be the best type in Sind for quality, having a long fine grain and a thin shell and tight husk. It is also highly scented, and has been valued at a higher price in the market than the *Jajai-Sugdasi*, which has the highest reputation among the scented Sind varieties. It ripens along with the latter, and in 1926 has given (in six replications) six per cent. higher yield. The existence of such a type has been hitherto unsuspected, but it indicates the possibilities of acclimatisation even under conditions so widely different as Bengal and Sind.

Apart from the above case, the efforts at introducing suitable varieties for Sind from outside have not been very promising, but details regarding them may be given.

Japan rices. Seeds of the following Japan varieties have been tried under Upper Sind conditions : —*Aiokoku, Kamino Shiratma, Oba, Myakoe, Okawa-shiragasi, Shiranki, Omachi, Magatma* and *Sekitori.* All of these are dwarf in habit of growth, hardly attaining a height of eighteen inches. Two of the varieties, namely *Kamino* and *Oba* flowered in twenty-eight days after transplanting, but none of them matured grain. They were largely affected by the disease known as *Sclerotial* disease caused by the fungus *Sclerotium oryzae.*

Rices from the Central Provinces (India) : -Nine varieties were tried under Upper Sind conditions, sent under the following names : *Kariasela, Khuraban, Kanta Saila, Bhadaw-Bhundi, Khoot Bohira, Bhat Mathura, Bhat Gurmatia, Bhat Pandari, Karia-Bohiri.* All of them were coarse grained, and have no characters which make them specially suitable for Sind.

Assam rices. No less than sixteen varieties from Assam were grown in Upper Sind. Most of them were high tillering and three of the varieties were specially interesting in this respect. These were (1) *Basmati*, (2) *Basant Bahar* (A. S. 224) (3) *Tipidumia Basant Bahar* (A. S. 224) is a very fine rice, and this combined with high tillering capacity indicates possible high value. *Tipidumia* is perhaps the most highly tillering rice we have got, though it is early and has a coarse red grain.

Bengal Rices. The following rices from Bengal (Dacca) have been studied in Upper Sind : *Suraj Mukhi, Katak Tara,* Jasa *balam, Dudsar, Indrasail, Dadkani.*

The last of these (*Dadkani*) is not a new introduction as it has been grown in Upper Sind for a number of years. It is a late variety and does not appear to be widely adaptable. It has, however, a very fine grain and is popular,—though the grain is not suited for parboiling. It has been compared with *Prong,* and *Jajai* in three successive years, as to time required for maturity and the yield per plant. The tests were made in eight replications in each case.

TABLE XVIII.

Comparative characters of Dadkani and Prong rice in Sind.

	Dadkani Rice	*Prong* (No. 65 or 36 Rice
1 Days needed to mature	Days	Days
1924	129	134
1925	130	130
1926	123	134
2 Yield per plant	Grm.	Grm.
1924	21·1	17·0
1925	15·2	14·0
1926	16·3	18·7
AVERAGE .	17·5	16·8

TABLE XIX.

Comparative characters of Dadkani and Jajai rice in Sind.

—	*Dadkani* rice	*Jajai* (No. 63 or 77 rice)
1. Days needed to mature	Days	Days
1924	124	120
1925	124	115
1926	118	123
2. Yield per plant	Grm.	Grm.
1924	24·1	22·0
1925	18·7	14·0
1926	15·2	17·5
AVERAGE .	19·3	17·8

It will thus be seen that this imported type (*Dadkani*) from Bengal has given at least equal yields at Larkana to those given by the other high quality scented rices of Upper Sind. On continued growth it has, however, been found by growers to be delicate and to be more susceptible to the leaf spot (*Helminthosporium*) disease, which has done so much damage in Upper Sind in recent years, and particularly in 1925.

Out of the other five Bengal rices mentioned above *Suraj Mukhi* and *Katak Tara* proved to be early when grown at Larkana, while the others were extraordinarily late. *Dudsar* ripened twenty six days later than *Jajai*, but gave 59 per cent higher yield. *Indrasail* ripened fortyone days later than *Jajai*, and gave 16 per cent. lower yield than the latter. These yields were taken in eight replications in 1925. These very late rices are, however, of little use in Sind owing to the failure of the water supply and to the liability to very great cold and even frost in December.

Rices from the Konkan. There have been worked out in recent years at Karjat in the Konkan a number of pure strains of the very valuable fine *Kolamba* rice, and several of these have been tested at Larkana (Upper Sind). These *Kolamba* rices have very small grains, and are valued higher than the local non-scented varieties, though they are not suited for parboiling. Trials with replication show that none of them yields more highly than the local selections from *Kangni* rice, while some of them (*Kolamba* No. 79 in particular) seem to be specially susceptible to the leaf spot (*Helminthosporium*) disease.

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APPENDIX II.

Length of earhead and number of branches per earhead in Sind rice varieties, 1923.

Variety	Mean length of earhead in inches	Mean number of earhead branches
Sighro	7·2	7·9
Parsad	7·5	8·6
Lari	7·7	9·6
Ganja	7·7	8·3
Jirashahi	7·6	10·5
Bidri	8·3	9·1
Kunjro	8·3	11·1
Ganjro	8·3	10·2
Red Kangro	8·1	8·6
Torh	8·1	9·3
New Type B.	8·5	8·5
New Type A.	8·5	8·5
Sathri	8·7	11·0
Ratrya	9·0	8·5
Pista	9·3	9·9
Sonahiri	10·0	8·5
New Type Y.	9·1	10·5
Motiaro	10·2	17·6
New Type Z.	10·7	12·2
Sada Gulab	10·7	8·9

APPENDIX III.

Number of spikelets per earhead in Sind rice varieties, 1923.

Variety	Number of earheads examined	Mean Number of spikelets per earhead
Lari	106	92·3
New Type B.	161	94·2
Sighro	205	94·7
Sonahari	180	95·5
Ganja	192	96·6
Ratriya	119	102·5
Prong	180	104·6
Red Kangro	147	106·3
New Type A.	185	109·3
Sada Gulab	117	110·6
Jajai	179	142·3
Torh	193	145·3
Gangro	..	146·4
Palwad	116	150·0
Sathri	176	158·5
Kangni	448	162·7
Ladri	182	163·9
Motiaro	155	196·1
Pista	111	205·8
Kanjro	179	253·6
Jaashahi	115	303·1

APPENDIX IV.

Yield of single plants (spaced 12 by 9 inches).

Variety	Yield per plant in grm.	Variety	Yield per plant in grm.	Variety	Yield per plant in grm.
Sind rices in 1924.					
1 Torh	38·32	2 New type Y	35·94	3 Motiaro	34·92
4 Kunjro	30·73	5 Sada Gulab	30·61	6 Dadkani	30·16
8 Bengalo	28·80	9 Red Kangro	27·78	10 Early Karjat	26·19
11 Pista	25·28	12 Sonahiri.	25·28	13 Ganjro	25·06
14 Sathri	23·47	15 Ganja	23·36	16 Parsad	22·68
17 New Type Z.	22·22	18 Bidri	21·77	19 Ratrya	20·86
21 New Type X.	20·18	22 Jirashahi	19·73	23 Sindhi Kambroo	18·25
24 Chajrai	18·14	25 Sighro	17·57	26 Lari	17·12
27 New Type A.	17·01	28 New Type B.	16·66	29 Barsati	14·17
30 New Type Za.	13·72	31 Bengal rice	6·57	....	..
Konkan rices, 1925.					
1 Kolumba 241	40·14	2 Kolumba 181	35·60	3 Kolumba 79	24·15
4 Kolumba 153	20·39	5 Kolumba 42	18·82	....	..
Bengal rices, 1925.					
1 Indra Sail	27·55	2 Dudsar	27·32	3 Jeshabalam	23·70
4 Dadkani	22·79	5 Surajmukhi	17·23	6 Katak Tara	11·90
7 Bengal rice	5·10	....	..	....	..
Assam rices, 1925.					
1 Tipidumia	38·14	2 Basmati	33·11	3 Basant Bahar A. S. 234	26·30
4 Nagra Sail	26·08	5 Lati Sail	26·08	6 Kartak Sail	22·79
7 George Sail	22·79	8 Raskadum	21·43	9 Barashmurti	18·81
10 Indra Sail	18·18	11 Tulsi Joha	18·14	12 Sail Badal	17·69
13 Basant Bahar 233	16·78	14 Kasalatha	15·08	15 Bir Pak	6·57
Central Provinces rices, 1925.					
1 Khuraban	32·0[illegible]	2 Bhat Gurmatia	31·41	3 Bhat Pandri	22·68
4 Karla bohiri	22·68	5 Karia Sela	21·20	6 Kanta Sela	15·08
7 Bhadun bhimdi	14·17	8 Bhat Mathura	7·14	....	..
Deep water Dacca rices, 1925.					
1 Secha Aman	5·21	2 Joyana	4·64	3 Narianda	4·53
Japan rices, 1925.					
1 Shiranki	7·59	2 Omachi	5·32	3 Seki Tori	3·85
4 Shiratama	2·38	5 Kamino	1·93	6 Magatama	1·70
7 Oba	1·02	8 Okwashiragasi	0·90	9 Alokoku	0·45
10 Myaku	0·34	....	..	....	

APPENDIX V.

Flowering and ripening periods of foreign varieties of rice as grown in Sind in 1925-26.

Variety	Days to flower from transplanting	Interval from flowering to maturity	Days to ripen from transplanting
Kolamba strains.			
Kolamba 79	69	26	95
,, 184	65	32	96
,, 153	70	15	115
,, 241	84	31	115
,, 42	89	34	123
Bengal varieties.			
Katak Tara	68	33	101
Suraj Mukhi	67	34	101
Dadkani	80	40	120
Jeshabalam	100	34	134
Dudsar	95	39	134
Indra Sail	110	32	142
Assam varieties.			
Basant Bahar AS 224	62	27	89
Tipidumia	61	34	95
Kasa Latha	66	36	102
Raskadum	65	37	102
Barashmurti	64	38	102
Tulsi Joha	74	30	104
Basmati	71	41	112
Kartik Sail	88	33	121
Basant Bahar 233	88	34	122
George Sail	83	39	122
Nagra Sail	94	40	134
Lati Sail	98	36	134
Bir Pak	100	38	138
Sail Badal	105	35	140

APPENDIX V—*contd.*

Variety	Days up to flowering	Interval	Days up to harvest
Assam varieties			
Indra Sail	104	38	142
Badsha bhog	100	48	148
Central Provinces varieties			
Karia Sela	67	36	103
Khuraban	71	32	103
Kanta Sela (Early)	65	43	108
Bhadun Bhundi	99	12	111
Khut Bora	74	40	114
Bhat Mathura	73	42	115
Bhat gurmatia	74	41	115
Bhat Pandri	79	36	115
Karia bohini	79	42	121
Deep water Dacca rice			
Narenda	99	33	132
Secha aman	99	55	154
Joyana	108	46	154
Japan varieties.			
Okwashiragasi	50	46	96
Shiranki	50	46	96
Omachi	48	48	96
Magatma	50	46	96
Seki tori	48	48	96
Aiokoku	48	60	108
Kamino	28	80	108
Shiratama	48	60	108
Oba	35	73	108
Myakoo	48	60	108

APPENDIX VI.

PART I.

Time of the day when opening of flowers takes place.

Variety	Number of flowers opened on one earhead								Unopened and abnormal	Total
	7-30	8-30	9-30	10-30	11-30	12-30	1-30	2-30		
1922.										
1. Kangni	0	0	10	46	87	13	0	0	2	158
2. Jajai	0	0	9	62	72	13	0	0	5	161
3. Prong	0	0	6	46	59	16	0	0	4	131
4. Sathri	0	0	7	21	73	20	0	0	2	123
5. Sighro	0	0	9	16	29	4	0	0	2	90
6. Sonahiri	0	0	4	63	51	17	0	0	3	138
7. Sada Gulab	0	0	0	34	57	24	0	0	3	118
8. Torh	0	0	2	33	104	21	0	0	4	164
9. Ganjro	0	2	0	10	54	7	0	0	2	75
10. Bidri	0	1	6	30	40	6	0	0	1	92
TOTAL	0	3	53	399	626	141	0	0	28	1,250
PERCENTAGE	0	0·24	4·24	31·92	50·08	11·28	0	0	2·24	100
1924.										
1. Dadkani	0·1	1·9	6·1	9·6	36·6	37·4	15·1	6·5	9·0	119·6
2. Motiaro	0	1·1	5·2	6·7	3·2	5·7	11·3	1·3	47·4	82·2
3. Lari	0	0·1	2·8	4·0	16·3	19·2	39·2	19·4	3·3	134·3
4. Ganja	0	1·2	5·8	5·8	14·2	38·3	35·5	35·6	5·8	142·2
5. Kangni	0	0·5	1·5	3·5	9·9	33·5	36·5	20·3	6·1	111·8
6. Kunjro	0	0·4	4·7	8·6	27·7	72·4	28·9	4·1	3·7	150·5
7. Koluba 42	0	0	4·3	13·0	30·9	63·6	48·5	16·7	13·5	190·5
8. Pista	0	0	6·0	20·1	43·1	73·3	36·2	9·8	11·6	200·1
9. Jirashahi	0	0	11·2	30·1	45·2	73·0	85·5	17·3	10·3	301·6
10. Bengal rice	0	0·1	5·3	13·9	17·6	27·0	36·8	19·4	5·5	125·6
11. Sighro	0·5	8·7	5·6	9·8	43·2	67·3	11·1	0	5·2	151·4
12. Bidri	2·7	5·2	8·1	21·0	56·8	39·5	3·0	0	4·8	141·9
13. Ganjro	0·3	0·6	5·1	6·5	30·6	51·5	7·1	0	5·7	107·4
14. Sathri	2·2	7·2	12·5	19·4	42·0	9·9	1·3	0	8·3	102·8
15. New type A.	18	16·6	13·2	19·9	34·0	11·6	1·1	0	4·3	118·7
16. Red Kangro	11·0	10·4	15·8	19·0	22·9	10·1	1·1	0	3·2	93·5
17. Kolumba 79	5·7	12·2	23·4	39·8	94·0	81·0	18·0	0	28·3	302·4
18. Parsad	28·3	29·6	28·1	13·3	17·7	25·2	11·1	0	11·6	167·0
19. Sonahiri	2·6	2·6	5·0	15·9	38·6	44·1	12·5	0	11·1	132·4
20. Sada Gulab	4·3	9·6	10·8	14·9	16·4	25·0	22·4	0	0	103·4
21. Torh	2·5	6·2	11·3	12·8	12·5	21·6	19·1	0	0	86·0
22. Prong	0·5	1·1	8·2	15·2	18·1	18·0	9·5	0	7·7	87·3
23. Jajai	2·1	2·3	8·8	10·3	17·6	24·8	17·5	0	0	83·4
TOTAL	80·8	117·8	209·6	332·5	689·1	902·0	508·3	180·4	206·4	3,226·0
PERCENTAGE	2·5	3·7	6·6	10·0	21·5	27·8	15·9	5·6	6·5	100

APPENDIX VI—*contd.*

PART II.

Period of flowering of a single earhead.

Variety	Number of flowers opened on each day: 1st	2nd	3rd	4th	5th	6th	7th	8th	Unopened and abnormal	TOTAL
1922.										
1. Kangni	20	54	51	25	6	0	0	0	2	158
2. Jajai	37	54	26	28	11	0	0	0	5	161
3. Sathri	28	36	28	21	8	0	0	0	2	123
4. Sighro	29	30	[illegible]	9	2	0	0	0	2	90
5. Ganjro	18	16	22	13	1	0	0	0	2	75
6. Bidri	11	33	28	16	3	0	0	0	1	92
7. Prong	13	29	32	20	20	5	8	0	1	131
8. Sonahiri	26	28	30	20	20	7	1	0	3	138
9. Sada Gulab	11	36	6	11	11	6	1	0	3	118
10. Toth	21	33	32	32	32	6	1	0	4	161
TOTAL	214	358	294	195	117	21	20	0	28	1,250
PERCENTAGE	17·12	28·64	23·52	15·60	9·36	1·92	1·60	0	2·24	100
1921 Early varieties.										
1. New Type A	11·5	29·0	32·0	25·5	13·4	0	0	0	4·3	118·7
2. Sighro	17·7	40·3	27·9	30·5	10·3	19·5	0	0	5·2	151·4
3. Bidri	18·6	49·4	33·1	25·4	9·6	1·0	0	0	4·8	141·9
4. Ganjro	20·1	34·8	22·3	13·0	10·8	0·7	0	0	5·7	107·4
5. Sathri	25·3	30·4	23·3	9·0	6·3	0·2	0	0	8·3	102·8
6. Red Kangro	25·3	31·2	19·5	9·0	1·9	0·4	0	0	3·2	90·5
7. Pista	10·3	15·9	20·9	41·8	36·6	39·3	20·7	0	11·6	200·1
8. Kolumba strain 79.	10·1	59·7	70·2	64·6	43·1	16·6	5·4	4·1	28·3	302·4
9. Parsad	14·0	31·7	45·1	31·7	8·5	11·2	3·6	2·8	11·6	167·0
10. Sonahiri	10·9	25·5	26·2	18·6	15·9	12·3	7·8	4·1	11·1	132·4
11. Jajai	8·2	20·0	18·2	12·4	7·6	8·2	6·1	1·8	0	83·4
12. Jirashahi	26·7	41·2	40·5	38·1	18·0	45·5	14·5	6·8	10·3	301·6
13. Kolumba strain 42.	8·3	14·7	37·7	32·7	37·8	32·7	12·4	0·7	13·5	190·5

APPENDIX VI—*concld.*

PART II—*concld.*

Period of flowering of a single earhead.

Variety	Number of flowers opened on each day											Unopened and abnormal	TOTAL
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th		
1924 Late varieties.													
14. Sada Gulab .	12.0	20.6	20.4	11.4	10.1	15.5	7.5	5.6	2.5	0	0	0	103.4
15. Torh . .	13.8	18.7	12.8	10.7	9.7	12.2	4.5	5.1	0.5	0	0	0	68.3
16. Motiaro . .	5.5	7.2	11.4	3.3	2.9	2.1	0.7	1.2	0.5	0	0	47.4	82.2
17. Dadkani .	4.6	12.6	12.6	20.8	19.3	15.7	15.4	5.3	1.7	0	0	9.0	113.8
18. Kunjro . .	11.7	27.5	36.6	5.9	12.3	12.5	9	5.1	0.1	0	0	3.7	150.5
19. Prong . .	6.5	21.9	2.7	9.7	7.7	9.6	6.2	5.4	0.5	0.4	0	7.7	78.3
20. Kangni .	19.3	17.1	21.7	15.3	11.1	4.2	5.8	4	8.7	1.0	0	6.1	111.8
21. Lari . .	6.0	9.3	19.1	21.8	24.0	15.8	15.6	7.2	7.2	3.5	3.5	3.3	134.3
22. Ganja . .	8.0	18.9	20.0	22.7	18.3	12.4	9.4	5.5	4.6	10	6.6	5.8	142.2
23. Bengal Rice .	7.0	7.8	16.7	14.5	6.4	11.2	16.4	13.1	2.8	7.2	11	5.5	125.6
TOTAL .	305.0	589.3	519.9	520.9	571.4	258	193.5	730	311	22.1	21.1	206.4	3,229
PERCENTAGE .	9.5	18.2	18.4	16.1	11.5	8.2	3	2.5	3	7	7	6.4	100

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Memoirs of the Department of Agriculture in India

Studies in the Shedding of Mango Flowers and Fruits, Part I

BY

P. V. WAGLE, M.Ag.
Mango Investigator, Ratnagiri Farm

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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CONTENTS

PLATES

STUDIES IN THE SHEDDING OF MANGO FLOWERS AND FRUITS, PART I.

BY

P. V. WAGLE, M.Ag.

(Received for publication on 12th September 1927.)

INTRODUCTION.

The mango is the premier fruit crop of the Bombay Presidency and in certain districts, notably in Ratnagiri and Thana, it forms the basis of considerable commercialised fruit industry. The whole status of the industry is rendered very uncertain, however, by the very great loss of flowers and fruit which occurs annually through shedding. The loss is always very great, but the variation in different years is enough to make the production in some seasons not more than a quarter to a third of that in others, while in each year, in one area or another almost the whole of the crop is lost.

This loss of crop through shedding of flowers and fruits, on trees whose flowers appear normally, is known locally as 'mango blight' and has been attributed to a multitude of causes. In popular estimation it is connected with the occurrence of rainy or cloudy weather or of excessive dew at the time of flowering and formation of fruits[1]. Its partial connection with certain species of *jassid* hoppers (*Idiocerus*) has been considered as proved[2 3 4]. The frequent occurrence of mildew on the inflorescences when shedding is going on has been noticed, though the connection of this fungus with the shedding itself has hardly been hitherto demonstrated. Other workers[5] have connected the loss with the infertility of a large proportion of the pollen, as a result of vegetative propagation through many generations; and, finally, Popenoe[6 7] has concluded that the problem is a physiological one connected with nutritional conditions, as influenced by changes in soil moisture and food supply, principally the former.

The matter is of sufficient importance to warrant a study of the whole question of the shedding of mango flowers and fruits on a somewhat broader basis than has

---

[1] McMurran, S. M. The Anthracnose of the Mango in Florida. *U. S. Dept. Agri. Bull.* 52 (1914).

[2] Ballard, E. Mango hopper control experiments. *Agri. jour. of India*, Vol. X (1915).

[3] Husain, M. A., and Puthi, H. S. Some experiments to control mango hoppers. *Rept. Proc. Fourth Ent. Meeting, Pusa* (1921).

[4] Note on Mango hopper and mildew. *Jour. Mysore Agri. and Expt. Union*, Vol. III (1921).

[5] Jivan Rao, P. S. Pollen sterility in relation to vegetative propagation. *Jour. Madras Agri. Students' Union*, Vol. XI, Nos. 9 and 10 (1923).

[6] Popenoe, W. The pollination of Mango. *U. S. Dept. Agri. Bull.* 542 (1917)

[7] Popenoe, W. Manual of Tropical and Sub-Tropical Fruits (1920).

been hitherto done, and the author has had the opportunity during the last two years (thanks to funds provided by the Sir Sassoon David Trustees) to commence the investigation of the problem in the centre of the most important mango producing area of the Bombay Presidency, Ratnagiri in the Konkan. The present memoir brings together most of the data hitherto obtained.

MANGO INFLORESCENCE.

The inflorescence of the mango has been several times described in detail in recent years [1], but the main point of importance in the present discussion is the fact that by far the largest proportion of the flowers in the inflorescence are staminate or male. The inflorescence, in fact, consists of both hermaphrodite or complete flowers and staminate or male flowers, and in the variety most largely and, indeed, almost exclusively cultivated in Western India on a commercial basis,—the Alphonso or *Hapuz* variety,—the proportion of complete flowers is very small. As all the author's experiments have been made with this variety, the normal position in this case may be indicated.

A very cursory examination of the inflorescences even of a single tree, and even when they are produced at the same time of year, shows that the proportion of male to complete flowers is very variable indeed. Taking the season as a whole at Ratnagiri, a study of seventy-three different inflorescences showed in 1925-26 a variation in the proportion of complete flowers from 2 to 55 per cent. In 1926-27 an examination of 319 flower heads showed a variation of from 0 to 30 per cent. of complete flowers. We have now to study the fact of this extraordinary variation and to attempt to correlate it with other factors in determining the character of the inflorescence.

From the results of 1925-26, details are available with regard to forty inflorescences occurring on thirteen trees. A full statement will be found in Appendix I. But the figures show that out of forty cases —

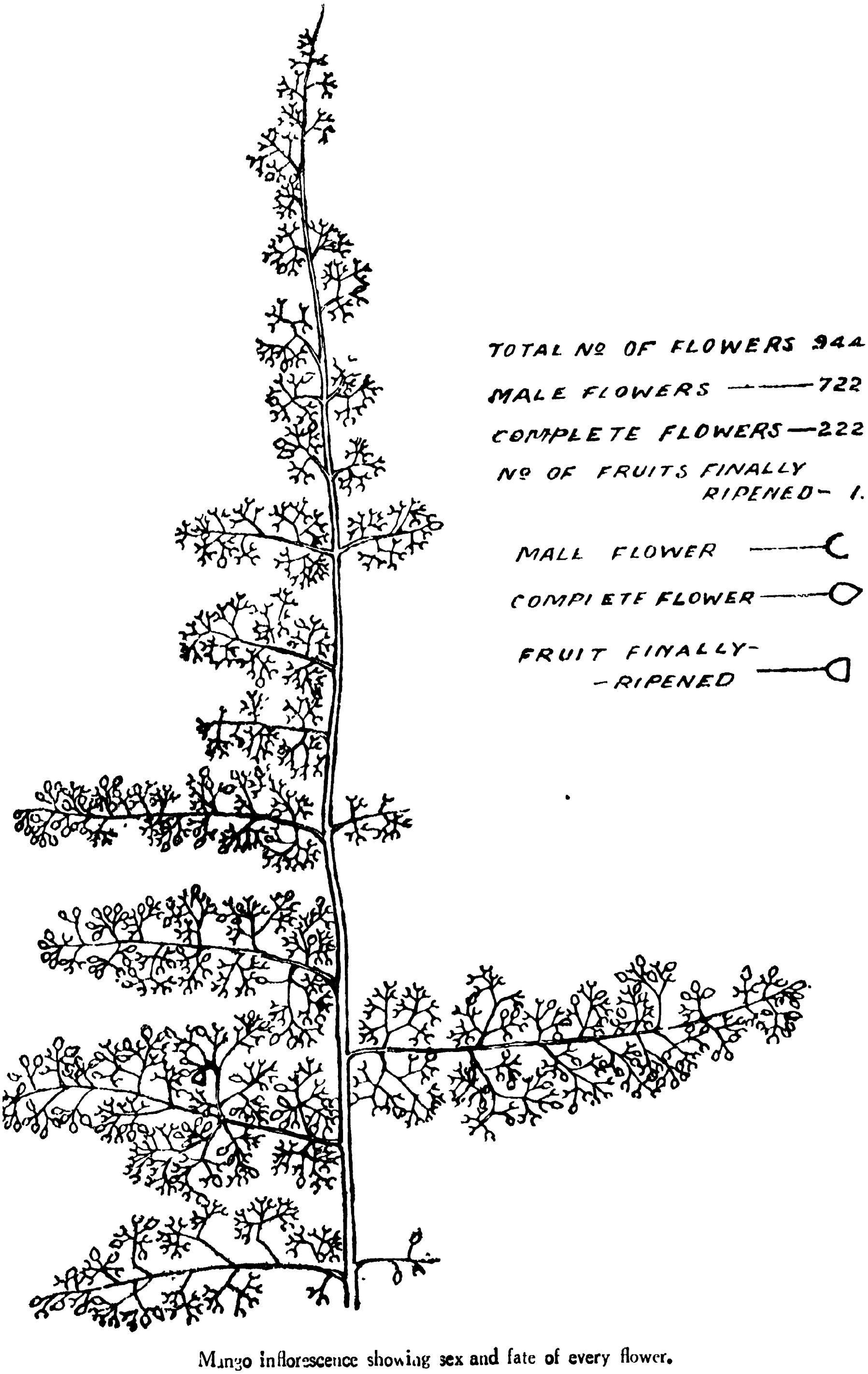
2 cases gave under 5 per cent. of complete flowers.
6 cases gave from 5 to 10 per cent. complete flowers.
10 cases gave from 10 to 20 " " "
7 cases gave from 20 to 30 " " "
8 cases gave from 30 to 40 " " "
5 cases gave from 40 to 50 " " "
2 cases gave over 50 per cent. complete flowers.

In 1926-27, the proportion of complete flowers was far lower than in the previous year, and an examination of 319 inflorescences from seventeen trees gave the following figures—

265 cases gave under 5 per cent. of complete flowers.
27 cases gave from 5 to 10 per cent. of complete flowers.
21 cases gave from 10 to 20 " " "
4 cases gave from 20 to 30 " " "
2 cases gave from 30 to 40 " " "
No cases gave over 40 per cent. of complete flowers.

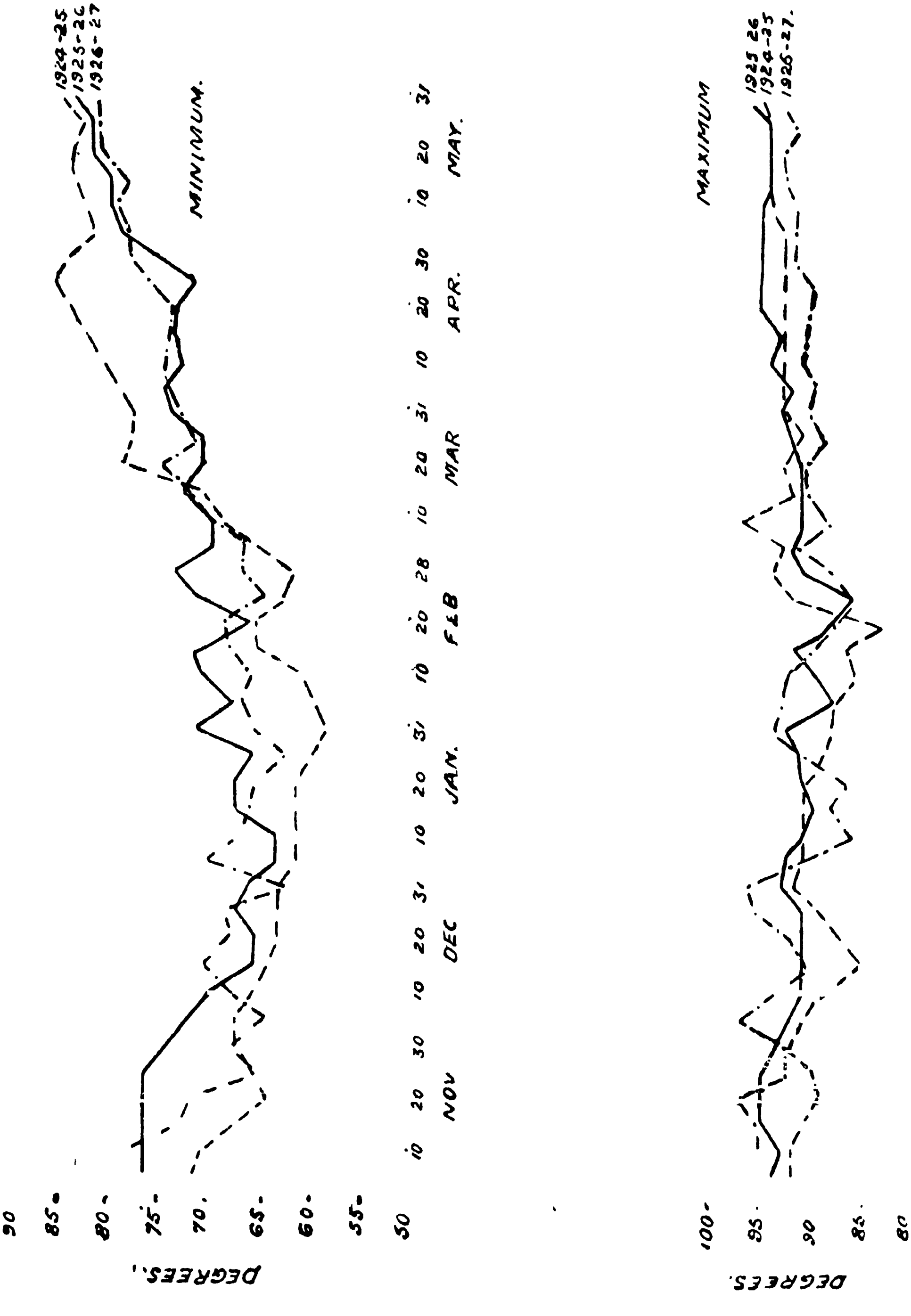
---

[1] Burns, W., and Prayag, S. H. Notes on the Infloresence and Flower of the Mango Tree. *Poona Agri. Coll. Magazine*, Vol. II (1911) p. 226.
Popenoe, W. The Pollination of the Mango. *U. S. Dept. Agri. Bull.* 542 (1917).



Mango inflorescence showing sex and fate of every flower.

PLATE II



Temperature Graphs at Ratnagiri, 1924—27

It is difficult to account for the very great difference between the two seasons, and it would seem to indicate some very deep distinction in the weather characters at the time the inflorescences were forming. But this deep distinction is not easily detected from the records.

Considered as a fruit producing season, the year 1925-26 was very unsatisfactory, being a year following an extraordinarily abundant crop. The flowering was very late and scarce, and only started early in January in Ratnagiri instead of, as usual, in November. The flowering this year was in fair flushes, which were not, however, very distinct. The first and the largest took place in the first week in January, and the height of each of the others followed at an interval of about a month. Except early in January there was no cold weather, in contrast to the previous year when long continued cold weather occurred. Plate II shows this difference clearly. There was rain in November and January, which was exceptional but no rain from February onward and little dew.

In 1926-27 the season was on the whole a good one. The flowering took place in three fairly distinct flushes in November to December, early January and early February. There was no rain during the flowering season, but much dew during February and March.

The following Table shows the rainfall, month by month, in the three seasons ending 1927.

TABLE I.

Rainfall at Ratnagiri, 1924-27.

	1924	1925	1926	1927
	In	In	In.	In.
June	29 28	29 24	20 98	..
July	39 31	14 24	33 84	..
August	14 65	21 17	49 67	..
September	8 16	4 26	12 90	..
October	2 12	1 87	1 37	..
November	*nil.*	1 15	*nil*	..
December		*nil*	*nil*	..
January		.	0 65	*nil.*
February			*nil*	*nil*
March	..	..	..	*nil.*
April	.		..	0 04
May		1 3	..	0 42

It would seem from this that the large proportion of complete flowers in the inflorescences in 1925-26 accompanied an unusually small amount of flowering. In 1926-27, when flowering was generally much more profuse, the proportion of complete flowers, capable of producing fruits, was very much lower. There seems some evidence that the absence of cold weather discourages flowering, but it is by no means conclusive.

Two points of interest now arise. Is the variation in the proportion of complete flowers during the same season due to (1) the individuality of trees, or, in other words, is the variation on one tree less than the general variation above noted and (2) the time of the season when the inflorescences are formed, or, in other words, is the proportion of complete flowers different in the first, second and third flushes?

The second point may be first considered, and in this matter data can only be presented for 1926-27. But here the proportion of *complete* flowers in the inflorescences of the different flushes found by examination of a large number of such inflorescences was as follows:—

TABLE II.

Proportion of complete flowers in different flushes 1926-27.

Flush	Number of inflorescences examined	Range of variation	Average
		per cent	per cent.
1st flush	159	0 to 15·1	1·5
2nd flush	80	0 to 34·9	7·0
3rd flush	80	0 to 30·2	3·4

The proportion of flower heads with different percentages of complete flowers in the inflorescences is shown in the following table.

TABLE III.

Proportion of flower heads with different percentages of complete flowers, 1926-27.

Percentages of complete flowers	Number of individuals: First flush	Second flush	Third flush
0·0 to 0·25	27		
0·25 to 0·5	14	5	21
0·5 to 1·0	31		
1·0 to 1·5	31		
		19	13
1·5 to 2·0	15		
2·0 to 2·5	15		
2·5 to 3·0	9	15	27
3·0 to 4·0	7		
4·0 to 6·0	6	12	5
6·0 to 10·0		9	9
10·0 to 14·0	4	10	4
14·0 to 20·0		6	1
20·0 and above	..	4	..
	159	80	80

These figures would suggest that the proportion of complete flowers is likely to be higher in the second flush, that is to say, in the middle of the flowering season,

han in the first and third. This conclusion may be considered, however, as very entative. It may be noted that the inflorescences of the first flush were very large, much larger than the later ones. Thus the average number of flowers (complete and staminate together) in the flowerheads of the first flush was 6,191 (from a study of 20 flower heads), in those of the second flush was 2,435 (from a study of 0 flower heads), and in those of the third flush was 2,689 (again from a study of 10 flower heads). It is, therefore, possible that in larger flowerheads the proportion is likely to be low irrespective of the flush, and that the low proportion in he first flush is likely to result because the flowerheads of that flush are usually large. The average proportion of complete flowers in inflorescences of different sizes, taken from all the flushes, was as follows in 1926-27.

'otal number of flowers per inflorescence	Average proportion of complete flowers
Below 2,000	5·31 per cent
2,000 to 4,000	3·17 ,,
4,000 to 6,000.	2·40 ,,
6,000 to 8,000.	1·53 ,,
Over 8,000	1·51 ,,

These figures certainly suggest that the large flowerheads *do* have a smaller proportion of complete flowers, and it may be noted, in passing, that this agrees with the opinion of the mango growers, who look upon large inflorescences as largely barren.

As regards the individuality of the different trees in the matter of the proportion of complete flowers we have records from a number of flowerheads on seventeen trees. Eight of these are from trees which chiefly flowered in the first flush, and nine from trees which gave its principal crop in the second and third flushes. The following are the results tree by tree.

TABLE IV.

Proportion of complete flowers on different trees.

Number of trees	Number of flowers examined	Percentage of complete flowers: Range	Average
		Per cent.	Per cent.
1. Main flowering in 1st flush.			
1	48	0·0 to 4·0	1·0
2	8	0·1 to 3·1	0·9
3	24	0·0 to 2·7	1·2
4	16	0·5 to 18·2	5·5
5	16	0·0 to 2·1	0·8
6	32	0·0 to 29·3	3·9
7	15	0·4 to 7·3	2·5
8	24	0·4 to 26·3	5·5

TABLE IV- *contd.*

Number of trees	Number of flower examined	Percentage of complete flowers	
		Range	Average
II. Main flowering in 2nd and 3rd flush.			
		per cent.	per cent
9	32	0·0 to 7·4	1·7
10	16	0·1 to 27·5	6·2
11	16	1·0 to 6·8	3·4
12	16	0·0 to 10·8	3·6
13	16	0·0 to 34·9	4·0
14	16	1·0 to 30·2	10·3
15	8	1·5 to 11·1	6·7
16	8	0·0 to 8·0	2·1
17	8	0·4 to 4·3	2·7

When we compare these figures for individual trees with the general range for all flowers of each flush taken together (Table III) it is seen that the range on one tree may be nearly as great as for the whole of the inflorescences on a number of trees and hence it cannot be considered that a large proportion of complete flowers or *vice versa* is characteristic of particular trees.

The number of complete flowers in any inflorescence represents the maximum possible fruit production. But the *actual* fruit production is, under any circumstances, very small in relation to the number of such flowers. In country seedling mangoes the number of fruits may go to eight or ten per inflorescence, but in the Alphonso variety, the maximum the author has ever seen is five ripe fruits per inflorescence. This number is, however, very rare. Four fruits per flower head is uncommon, and three not very frequent. Most inflorescences produce not more than one or two. And yet the proportion of flowers fertilised is very large and the number of fruits actually formed is from four to twelve times as many as the number that finally mature. The actual figures from a detailed study of seven flowerheads 1925-26 and of twenty flowerheads in 1926-27 gave the following figures.

TABLE V.

Proportion of complete flowers shed in different stages.

	1925-26	1926-27
Flowerheads examined	7	20
Total complete flowers in these heads	1,558	2,151
	Per cent.	Per cent.
Proportion shed before fertilisation	38·4	53·5
Proportion shed just after fertilisation . . .	56·1	44·3
Proportion shed before fruit is of the size of a marble	3·6	1·0
Proportion shed at later stage	0·8	0·9
Proportion forming mature fruits	0·8	0·3

It is to the study of the causes of this enormous amount of shedding that the remainder of the present memoir will be devoted.

PLAN AND METHOD OF STUDY.

Starting with the idea that the shedding of flowers and fruits might be due either wholly or partly to (1) mango *jassid* hoppers, (2) mildew, (3) rainy and cloudy weather, (4) excessive dew and (5) lack of available plant food, observations were made in order to find out the relation of these different causes to the phenomenon under study and experiments were planned to examine the effect of each of these individual factor separately. More attention has been paid to the first two factors, namely, mildew and *jassid* hoppers. For studying the nature of the flowers, they were carefully examined and a record of the sex of the flowers in all the flowerheads has been kept. For the study of *Jassid* hoppers and mildew, seven sets of flowerheads were treated as described below and their behaviour noted from time to time. Ten flowerheads only could be treated during the first year and forty during the second year in each set of the experiment. Flowerheads for each method of treatment were in most of the cases selected from the same tree and even from the same branch.

1. Under open conditions, with no treatment.
2. Under open conditions and sprayed with Fish oil rosin soap to kill hoppers; but not sprayed for mildew.
3. Under open conditions, and sprayed against mildew with Bordeaux mixture; but not sprayed against hoppers.
4. Under open conditions and sprayed with a mixture of Fish oil soap and Bordeaux mixture to destroy both hoppers and mildew.

5. Bagged to exclude hoppers and no other treatment.
6. Bagged to exclude hoppers and inoculated with hoppers.
7. Bagged to exclude hoppers and inoculated with mildew.

For studying the question as to whether the loss of flowers and fruits is brought on by insufficiency of plant food or water, manuring and irrigation experiments were also conducted and these plants were also kept under observation.

With a view to find out what happens to the numerous flowers, appearing on a flowerhead, a large number were kept under close observation. The shed flowers and fruits from all the flowerheads under treatment were collected every alternate day during the first year and once every week during the second year, from the bags in the case of the bagged flowerheads, and in big tin funnels, provided with cloth bags at the bottom in the case of the open flowerheads. After a careful examination under a lens, the flowers and fruits were separated and classified according to the size and cause so far as this could be made out from the external symptoms. Those for which no explanation could be given were classed as unknown.

Besides weekly notes were kept after careful inspection of all the flowerheads as regards the extent of infection of hoppers, mildew, etc., and also the setting of fruit. These were compared from time to time with the actual shedding from the different causes. The results of various methods of treatment will be detailed later.

Details of the method of treatment. The work of the first year having started very late, flowerheads of the first flush could not be taken up for treatment. But of the ten taken, five were from the second and five from the third flush. In the second year, out of the forty flowerheads, twenty were from the first flush, ten from the second and ten from the third.

Sprayings of Bordeaux mixture (5·5·50) and Fish oil rosin soap solution (1 per cent. strength of the soap manufactured by the Government Soap Factory, Calicut, was used during the first year, while during the second year ½ per cent. strength of the soap prepared by the Dharamsi Morarji Chemical Co., Ambarnath was found quite effective) and a combined spray of both in the same proportions were given during the season to the respective series according to the requirements till the fruits had developed. The dates of the sprayings are as under :—

TABLE VI.

Dates of spraying mango trees.

1925-26				1926-27					
No.	Second flush	No.	Third flush	No.	First flush	No.	Second flush	No.	Third flush
1	25th Feb.	1	3rd March	1	16th Dec. .	1	13th Jan.	1	5th Feb.
2	8th March	2	17th ,,	2	21st ,, .	2	21st ,, .	2	11th ,,
3	17th ,, .	3	24th ,, .	3	27th ,, .	3	31st ,, .	3	21st ,,
4	24th ,, .	4	8th April .	4	7th Jan. .	4	15th Feb. .	4	3rd March
5	8th April. .	5	16th ,, .	5	22nd ,, .	5	3rd March .	5	17th ,,
6	16th ,,								

Mildew was inocu'ated first by preparing a mixture of spores obtained from scraping already affected flowerheads in water and applying the same to the healthy ones with a brush. Later on it was found that inoculations could be done more conveniently and effectively by vigorously shaking affected flowerheads just near the healthy ones. The dates of the inoculations are given below :—

TABLE VII.

Dates of mildew inoculations.

1925-26		1926-27		
Second flush	Third flush	First flush	Second flush	Third flush
24th February .	3rd March .	30th December to 1st January.	16th and 17th January.	11th February.

The hopper inoculations were carried out by letting small nymphs of hoppers of the species (*Idiocerus niveosparsus*) the predominent species found in the Konkan on the flowerhead and repeating the inoculation from time to time as they flew off after hatching into adults. The details of the inoculations are as under :—

TABLE VIII.

Dates of inoculations with Jassid *hoppers.*

1925-26				1926-27					
SECOND FLUSH		THIRD FLUSH		FIRST FLUSH		SECOND FLUSH		THIRD FLUSH	
Date	No. of nymphs	Date	No. of nymphs	Date	No. of nymphs	Date	No. of nymphs	Date	No. of nymphs
23-2-26 .	10	7-3-26 .	25	28-12 26 to 1-1-27	25	18 1-27 .	25	22-1-27 .	25
27-2-26 .	5	10-3-26 .	25	4-1-27 to 6-1-27	25	24-1-27 .	25	28-1-27 .	25
8-3-26 .	5	18-3-26 .	50	10-1-27 to 12-1-27	25	25-1-27 .	25	31-1-27 .	25
12-3-26 .	10	26-3-26 .	50	15-1-27 .	25	26 1-27 .	25	3-2-27 .	25
13-3-26 .	10	31-3-26 .	20	21-1-27 to 26-1-27	25	29-1 27 .	25	5-2-27 .	25
14-3-26 .	10	1-4-26 .	20	29-1-27 .	25	31-1-27 .	25	10-2-27 .	25
26-3 26 .	25	2-4-26 .	10	2-2-27 .	25	3 2 27 .	25	14-2-27 .	25
31-3-26 .	10	..	..	9-2-27 .	25	9-2-27 .	25	21-2-27 .	25
1-4-26 .	10	..	..	14-2-27 .	25	14-2-27 .	25	25-2-27 .	25
2-4-26 .	5	..	..	19-2-27 .	25	..	..	3-3-27 .	25
								8-3-27 .	25
TOTAL .	100		200		250		225		275

Further, some trees were either wholly or partly sprayed with Bordeaux mixture, Fish oil soap solution and a combined spray of both Bordeaux mixture and Fish oil soap to destroy the natural mildew and hoppers. Control was kept on the same tree or on the adjacent one. The number of flowerheads that appeared on each of these trees was counted, so also the number of fruits harvested.

Certain manuring experiments were conducted to see if the blight be due to want of food supply. The manures were given in two doses in February and March during the first year and in September and December during the second year. The details of the manures is given below. The quantities are per tree.

TABLE IX.

Manurial treatments used.

1925-26				1926-27			
1ST DOSE		2ND DOSE		1ST DOSE		2ND DOSE	
Name of manure	Quantity	Name of manure	Quantity	Name of manure	Quantity	Name of manure	Quantity
	lb.		lb.		lb.		lb.
Sulphate of ammonia	3	Sulphate of ammonia.	2	(1) Bone superphosphate.	6	(1) Bone superphosphate.	4
Bone super-phosphate.	6	Bone super phosphate.	1	(2) Bone superphosphate and	6	(2) Bone superphate and	4
				nitrate of soda.	1	nitrate of soda.	3
				(3) Bone superphosphate, nitrate	6	(3) Bone superphosphate, nitrate	4
				of soda and	4	of soda and	3
				sulphate of potash.	1	sulphate of potash.	3

The trees were irrigated with nearly one acre-inch of water every week from the time of the application of the manure to the middle of April ; other trees being watered for comparison . A record of the flowerheads and the number of fruits was kept in each case.

PHENOMENON OF FLOWER AND FRUIT SHEDDING.

Figures have already been given which indicate, for a number of complete flowerheads, the actual loss by shedding at different stages of the development of the inflorescence. These show that in the two years 38·1 and 53·5 per cent. respectively of the complete flowers shed before fertilisation, and 56·1 and 41·3 per cent. almost immediately after fertilization before the fruit was the size of a small marble. Thus in both years 94·8 per cent. were shed in these early stages, leaving only 5·2 per cent. of the complete flowers to develop fruits which even reached the small size indicated.

It is now necessary to study this phenomenon in more detail.

The shedding of the unfertilized flowers generally begins on the fourth day after the opening of the flower and of the fertilised ones after a week or ten days. If the shed flowers and fruit are classified week by week, it is noticed that the shedding increases upto the fourth week and then it gradually falls off. This can be seen from the accompanying table in which figures are given calculated for ten thousand complete flowers. The figures are only given for the third flush of 1925-26, when there were no *jassid* hoppers and little mildew and for the first flush of 1926-27 when there were no hoppers and practically no mildew was detected.

TABLE X.

Flowers shed at different stages.

1925-26				3RD FLUSH				1926-27				1ST FLUSH			
Week ending	Complete flowers before fertilisation	Fruit within 0·2 cm.	Fruit from 0·2 to 0·4 cm.	Fruit from 0·4 to 0·8 cm.	Fruit from 0·8 to 1·5 cm.	Fruit from 1·5 to 3·0 cm.	Fruit above 3·0 cm.	Week ending	Complete flowers before fertilisation	Fruit within 0·2 cm.	Fruit from 0·2 to 0·4 cm.	Fruit from 0·4 to 0·8 cm.	Fruit from 0·8 to 1 5 cm.	Fruit from 1·5 to 3·0 cm.	Fruit above 3 cm.
13-3-26	375 3	242 8	66 2	..	..	..	..	15-1-27	241 74	55 78	27·88	..	..	..	..
20-3-26	662 3	485 6	176 6	22 1	..	..	..	22-1-27	381 21	213 85	120 ·7	27 88	..	..	..
27-3-26	838 9	353 2	441 5	110 4	22 1	..	..	29-1-27	404 46	167 36	176 66	18 59	..	..	..
3-4-26	905 1	1,258 3	662 3	110 4	..	..	..	5-2-27	1,143 65	543 93	478 84	27 88	..	..	..
10-4-26	198 7	309 1	66 2	22 1	..	..	..	12-2-27	822 87	460 25	232 45	51 13	23 24	..	..
17-4-26	198 7	132 5	110 4	22 1	66 2	..	..	19-2-27	748 45	320 78	278 94	41 84	23 24	4·66	9 29
24-4-26	331·1	154 5	154 5	..	..	44 2	..	26-2-27	567 17	278 94	264 99	37 18	74 36	37 36	..
1-5-26	397 4	662 3	331 1	..	..	66 2	..	5-3-27	260 34	134·82	60 43	18 59	41·84	18 59	4 66
8-5-26	..	..	..	..	..	..	..	12-3-27	776 38	223 15	88 33	18 59	..	4 66	..
								19-3-37	..	..	..	..	..	..	4·66
								26-3-27	.	..	..	..	..	..	4·66
								16-4-27	..	..	..	..	..	..	4 66
TOTAL .	3,907 3	3,598·2	2 008 9	287 0	88 3	110·4	..	TOTAL .	5 346 30	2,398 86	1,729 39	241 68	162·68	65 27	27·93

In order to form an idea of the age of the shed fruit, measurements of a numb of growing fruit were kept from the time of the fertilization to the time of the harves It was observed that the fruits which are going to shed, gradually slow down growth a few days before shedding and ultimately stop growth altogether, dry u and fall. The following may roughly be taken as the rate of growth of a health fruit.

TABLE XI.

Rate of growth of a healthy mango fruit.

Age in days	Size in cm.	Average rate of growth per day	REMARKS
1 . . .	0·1	....	Unfertilised.
5 . .	0·2	0·025	Fertilised.
9 . . .	0·4	0·05	
17 . .	0·8	0·05	
25 . . .	1·5	0·08	
37 . . .	3·0	0·13	
55 . . .	5·5	0·14	
81 . . .	7·5	0·08	Mature fruit

With a view to ascertain the immediate causes of shedding so far as could b detected from the external symptoms, the shed forms were subjected to a carefu examination with a hand lens and certain obvious symptoms such as mildew, black spots etc., were noted. Those which could not be accounted for were classed a unknown. The following table gives the results of such a study for the three flushe on untreated trees in 1926-27.

TABLE XII.

External symptoms of shed flowers and fruits.

Flush	Total number of complete flowers	ACTUAL			PERCENTAGE		
		with mildew	with black spots	Unknown	With mildew	With black spots	Unknown
First . .	2,151	35	40	2,070	1·62	1·85	96·22
Second . .	1,264	142	11	1,108	11·23	0·87	87·66
Third . .	852	382	7	462	44·83	0·82	54·22

It will be seen from this that the shedding of a very large percentage cannot be accounted for by any obvious external appearance. There is a large percentage of mildew affected forms in the third flush only when there was severe mildew attack. The mildew went on increasing from flush to flush. Nothing has been so far ascertained as to the nature of the black spots on the very very small fruits which appeared in certain cases to be associated with this shedding. The nature and action of the mildew will be considered later.

In planning the experiments which have already been indicated, it was originally supposed that the treatments to be used would themselves exert little or no direct effect on the falling of the flowers. This has proved not to be the case, and the study of the bagged flower heads in particular has been very instructive in this connection.

Taking flowerheads which were enclosed in muslin bags before the flowers opened, the loss was very much greater than with flowers of the same trees exposed to the air. The number of flowerheads examined was 7 and 10 respectively in the unbagged and bagged series in 1925-26 and 20 in both cases in 1926-27.

TABLE XIII.

Comparison of shedding in bagged and unbagged flowerheads.

	1925-26		1926-27	
	Unbagged	Bagged	Unbagged	Bagged
Number of complete flowers opened . .	1,558	2,241	2,151	650
Percentage shed before fertilisation . .	38·1	54·0	53·5	87·6
Percentage shed after fertilization . .	60·8	45·8	46·3	12·3
Percentage of fruits ripened . . .	0·8	0·2	0·2	0·1

These figures show how bagging interferes considerably with fertilization, raising the percentage of complete flowers, which were never fertilized from 38·1 to 54·0 in 1925-26 and from 53·5 to 87·6 per cent. in 1926-27. The question of the activity of the wind and of insects on the pollination of the mango flower is one which has been much discussed, and in the present case the effect of the wind is reduced and that of insects wholly excluded.

Of the flowers which are fertilized, these figures gave no satisfactory evidence as to whether the bagging, that is to say, the absence of air movement and of insects causes shedding. In 1925-26, the proportion of flowers which fell after fertilization was larger in bagged flowers than in the open. In 1926-27 the opposite was the case. The actual proportion of *fertilised* flowers which gave mature fruits in 1925-26 was 1·25 per cent. in the unbagged heads and 0·5 per cent. in the bagged ones. In 1926-27 the corresponding figures were 0·6 per cent. in the open inflorescences and 1·25 per cent. in those contained in muslin bags. There is, therefore, no evidence

that absence of air movement or of insects has any special disadvantage, after fertilization has been achieved.

The effect of spraying the flowering trees with Bordeaux mixture, with Fish oil soap solution and with a combination of these two was decidedly interesting. We can, in one case, determine the effect of these sprays *themselves*, for in the 1st flush of flowers in 1926-27, there was practically a total absence of *jassid* hoppers and of mildew. The results, therefore, show the effect of the sprays on the flowers themseves, the sprays being applied on dates as follows, while the flush was going on:—(1) December 16, 1926 (2) December 21, 1926, (3) December 27, 1926 (4) January 7, 1927 (5) January 22, 1927.

The actual results are shown in the following table, the figures being from twenty heads in each case:—

TABLE XIV.

Effect of sprays on shedding in mango flowers.

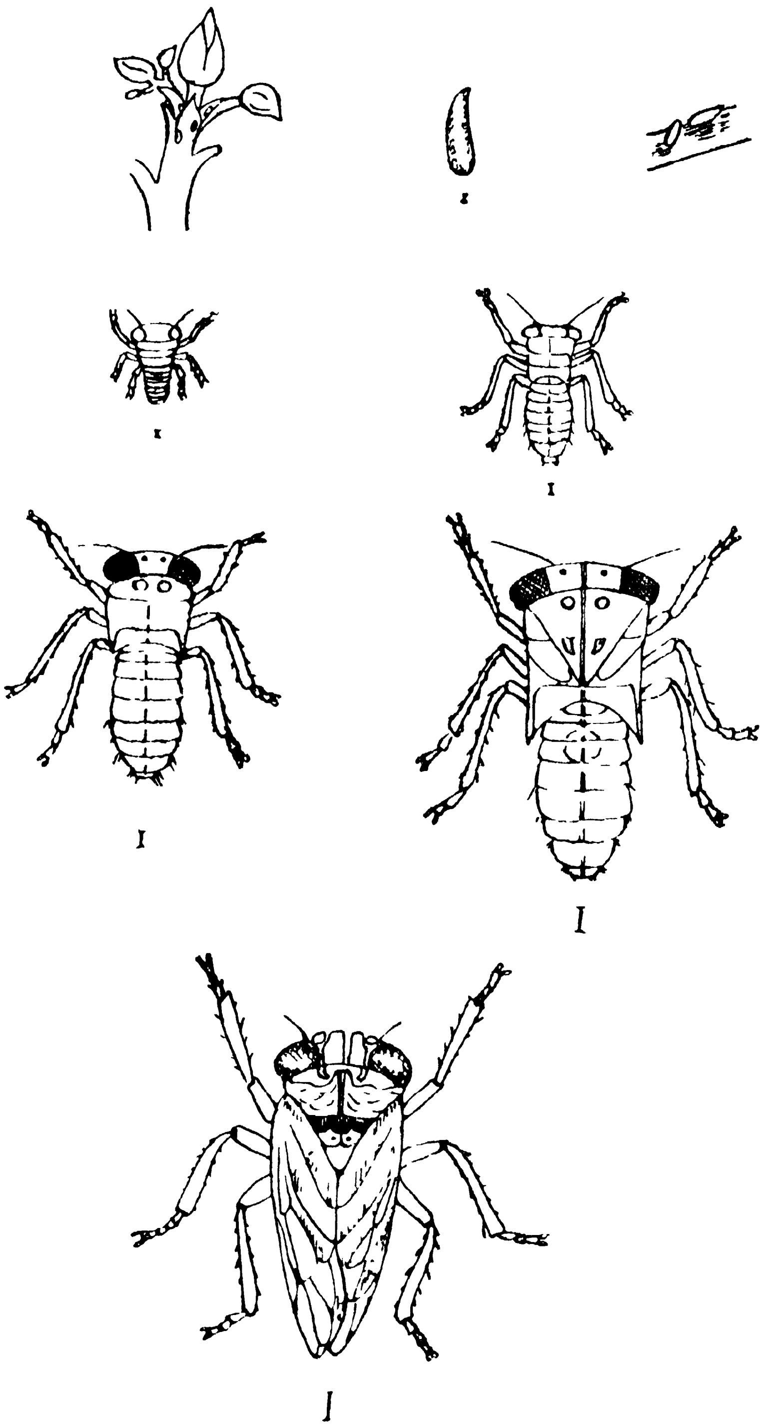
Treatment	Complete flowers examined	Proportion shed (a) Before fertilisation	Proportion shed (b) After fertilisation	Proportion of ripe fruit
		Per cent.	Per cent.	Per cent.
1. Without treatment	2,151	53·5	16·3	0·28
2. Sprayed with Bordeaux mixture . .	2,785	65·2	34·5	0·32
3. Sprayed with Fish oil rosin soap . .	2,190	58·6	41·1	0·27
4. Combined spray of (2) and (3)* . .	1,173	53·3	46·5	0·26

These figures show that the number of fruits ripened for a given number of complete flowers is hardly affected by the spraying treatment. If anything the Bordeaux mixture seems to have a somewhat beneficial effect, and leads to the ripening of a slightly larger number of fruits. On the other hand, when this spray is used, there is a distinctly larger number of flowers which shed without fertilisation. The other sprays seem to have had little effect at any stage of the development of the inflorescence.

Such being the normal shedding of flowers and young fruits with Alphonso mangoes grown at Ratnagiri and the influence upon it of bagging the flowers and of spraying with various materials, the next point is to determine the effect upon it of the two agents which have been charged with being responsible chiefly for the damage,—namely the *jassid* hoppers (*Idiocerus* sp.) and the mildew, which are so frequently found in connection with it. The experiments made have dealt chiefly with the effect on the shedding, of excluding these agents by spraying with materials as above mentioned which exclude their activity. Before describing the results of these experiments, a brief account of these two agents may be given.

* Only 19 flowerheads were examined in this case.

PLATE III.



Mango Jassid hopper (*Idioccrus nivcosparsus*).

Mango jassid hopper.

The mango hoppers have been considered as a very serious pest of mangoes and the various species of *Idiocerus* have been several times described, the latest account being given by Afzal Husain and Pruthi.* These authors only give an account of two species of these hoppers, namely, *Idiocerus atkinsoni* Leth and *Idiocerus clypealis* Leth. In a note to the paper referred to, Kunhi Kannan has indicated that he has worked out the life history of the third species known to be present on the mango tree, namely *Idiocerus niveosparsus* and this last has been found to be the most frequent and apparently the most injurious at Ratnagiri. The notes which follow refer to this last named species.

The method of studying these insects under controlled conditions adopted, was to enclose a fresh mango flower shoot in a small glass jar. A cloth bag open at both ends was prepared and carefully tied round the mouth of the jar at one end. The flower shoot was then kept in the arrangement thus made, the other end of the bag being tightly tied round the branch producing the flower shoot. Thus the flower shoot is completely enclosed in the jar. A fertilized female adult hopper with a swollen abdomen was caught and enclosed in the jar for one night and then removed. The development of the eggs was then carefully watched from day to day.

The following notes represent the life history as thus worked out at Ratnagiri, which differs markedly from that found by Afzal Husain in the Punjab.

The eggs are laid in the mid rib of the tender leaves generally on the lower surface, or in the axis of the flowerhead. They are almost cigarshaped tapering at one end and slightly round at the other. They are about 1 millimeter in length. They hatch in five to six days. The nymphs when hatched are also about 1 millimeter in length. The adult at Ratnagiri comes out after 10 to 11 days. Thus the whole life history from the laying of the eggs to the emergence of the adult hopper is sixteen to seventeen days.

Two adults enclosed in the way above described laid fourteen and sixteen eggs respectively in one night. They have been noticed to breed at any time of the year provided there is suitable food material for the nymphs in the form of flowerheads or tender vegetative shoots.

The adults of *Idiocerus niveosparsus* are always found on the *leaves* of mango trees except at the flowering season when they mostly rest on the flower shoots. The same is true of those of *Idiocerus clypealis*. But the adults of *I. atkinsoni* are mostly found on the stems by day and on the under surfaces of leaves at night. *Idiocerus niveosparsus* is sometimes also seen on leaves of various species of citrus fruits. Adults of all the species enclosed in a cage on a mango stem without any foliage inside are found to die within a day, while those with foliage inside are able to live for a long time. This shows that the adults feed on the leaves when there are no flowerheads. The hoppers are very susceptible to high temperatures, and

* Proceedings of the Fifth Entomological Meeting, Pusa, p. 252 (Calcutta 1924).

die very quickly if kept in a tube in the sun. If kept in a cool place, they are ab to live for a long period. Gardens thickly planted and with shade all over, harbou very large numbers of them and are thus more affected.

During the flowering season both adults and nymphs are found, when presen at all, in very large numbers on the inflorescences, and, in fact, it appears as if th opening of the flowers attracts the adult hoppers from the leafy portions of the tre Once there, they suck vigorously at the stalks of the infloresecence, both the rach and the stalks of individual flowers. It is natural that by far the greatest damag is done by the nymphs, for these are very numerous on the flower head during th season, as will be seen from the figures given above as to the number of eggs lai per hopper.

The number of the hoppers present is very variable. In 1925-26, no extensiv appearence of these insects occurred at any time during the season from Februar when the observations began to the end of the flowering. In 1926-27, there wer very few during the first two months of the flowering season, namely November an December. Then, in January a very large number appeared at the time of th second flush of flowers. Thereafter they were very much reduced in number and were little visible during the third flush of the season. It thus appears tha there is considerable variation in the prevalence of the insect from season to seaso and also from period to period within each season. If this insect is the dominan agent in causing flower and fruit shedding, the proportion of such shedding shoul be very widely different in different parts of the same season.

We may, in fact, compare the loss at each stage on twenty flowerheads in th first and on ten flowerheads in the second flush of 1926-27. The first flush took place in the absence of hoppers or, at most, their presence to a very small extent At the time of the second flush they were present in abundance while, fortunatel there was very little mildew. The difference between the results with the first an second flush may, therefore, be put down largely to the hoppers. The figure obtained were as follows:

Proportion of shed flowers, 1926-27.

	1st flush (Hoppers absent)	2nd flush (Hoppers present)
Complete flowers produced and examined . . .	2,151	1,264
Proportion	Per cent.	Per cent.
a. shed before fertilisation	53·5	62·6
b. shed after fertilisation . .	16·3	37·2
c. of ripened mature fruit	0·28	0·24

There is, therefore, remarkably little difference in the total proportion of flowers and young fruits shed due to the presence of the hoppers. In their presence, the proportion shed before fertilization is greater, but the actual proportion of fruits ripened is only about 11 per cent. less, which hardly suggests that these insects, at Ratnagiri at any rate, are the principal agent in causing loss of flowers and fruit.

Direct experiments were, however, undertaken to determine the effect of the insects, by introducing them into bagged flower heads, as small nymphs. The number thus introduced per flower head has been shown on page 227 and varied from 100 to 200 in 1925-26, to 225 to 275 in 1926-27. When they become adult they were allowed to escape. The results on the flower heads so treated (ten in number) were compared with a similar number bagged but not inoculated, with the following results :—

TABLE XV.

Effect of inoculating flower heads with hoppers (Bagged heads).

	Flowers shed per 100 completed flowers formed		Ripe fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
1925-26	Per cent.	Per cent.	
1 Inoculated with hoppers	61·9	38·1	No fruits.
2. Free from hoppers	54·0	15·8	0·22 per cent.
1926-27			
First flush			
1 Inoculated with hoppers	90·1	9·9	No fruits.
2. Free from hoppers	87·5	12·3	0·15 per cent.
Second flush			
1 Inoculated with hoppers	80·3	19·7	No fruits.
2. Free from hoppers	82·3	17·5	0·17 per cent.
Third flush			
1 Inoculated with hoppers	74·6	25·1	No fruits.
2 Free from hoppers	76·3	23·5	0·18 per cent.

These figures, resulting from intensive inoculation with the hopper, show the possible effect of the insect in a really serious attack. The inoculations were usually made by introducing from five to fifty nymphs per flowerhead at the same time, a fresh lot being put in when the previous supply had all become adult. It may, therefore, be taken as proved that the insect *can* be the cause of the complete loss of the mango crop. How far it actually does cause such loss in practice in the mango growing area at Ratnagiri has already been studied above and will be considered further in connection with the treatments designed to exclude its influence on a large scale.

Flower mildew of the mango.

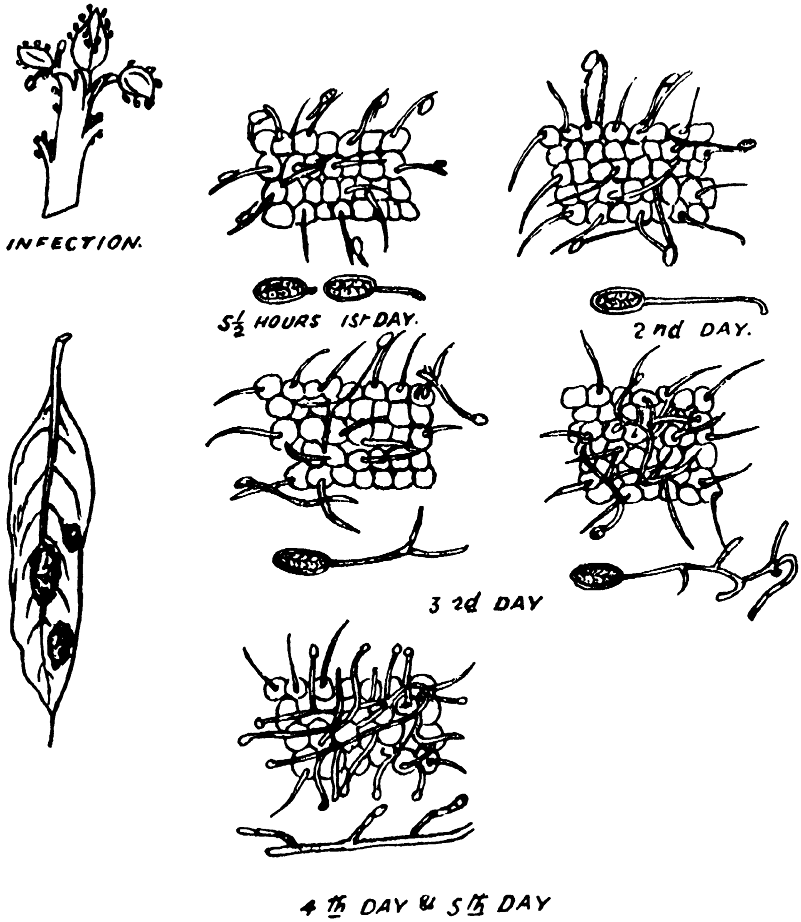
The possible importance of any mildew or other fungus in the falling of the mango flowers and fruits does not seem to have been fully recognised by previous workers on the subject. The fact that a mildew does occur on the mango inflorescence was noted in 1921 in Mysore [1] and Patwardhan remarks that the mildew *Erysiphe cichoracearum* did not appear in a mango garden in Thana (Bombay) in 1925 [2] By this it is assumed that this fungus had been detected on the flower heads in other cases. The fact that a fungus, resembling a mildew, is often found on fallen mango flowers seems, however, to be generally known and it is in fact prominent on many inflorescences especially during the latter part of the flowering season.

It is not proposed to present here a technical description of the fungus, which was identified by the Mycological authorities at Poona as *Erysiphe cichoracearum* D. C. If this identification is correct, it is the common mildew of tobacco, cucurbits and malvaceous vegetables in Western India. As it occurs on the mango inflorescence, the powdery incrustation shows innumerable hyaline oval spores sticking to each other and forming clusters (Plate IV). A transverse section of the affected part shows these spores to be borne at the tips of conidiophores which are divided by cross septa into two or three cells below the spore. The mycelium is quite superficial and none is found in the internal tissues.

For studying the different stages of the fungus, artificial inoculations were made. Some flowerheads were enclosed in muslin bags and thoroughly washed with disinfecting solution of mercuric perchloride (1 in 1,000) which was immediately washed off with distilled water. Then flowerheads affected with mildew were brought and shaken violently near the disinfected flowerheads so that the spores from the former were blown in profusion to the latter. The bags were immediately closed. Then scrapings were taken from the inoculated flowerheads twice every day and examined under the microscope. The life history was found to be as follows :—

The spores when blown off from an affected area easily stick to the hairy unopened flowers near the tip of the inflorescence. These germinate within five to seven hours.

[1] *Journal Mysore Agri. and Expt. Union*, Vol. III, No. I (1921).
[2] Patwardhan, G. B, *Ann. Rept. Agri. Dept. Bombay*, 1924-25, Page 157 (1924).



The flower mildew of the Mango (*Erysiphe* sp.).

The germ tube grows and within two days begins to branch and form mycelium. The mycelium then spreads profusely on the epidermal cells, which are killed by the feeding of the fungus and thus turn brown. On the fourth day several vertical bodies begin to appear from the mycelium. These are sporophores. On the fifth day, the mycelium becomes so profuse and so many sporophores with oval mature spores are produced that the whole of the affected surface puts on the characteristic white appearance of the powdery mildew. Thus the life history from spore to spore is about five days. The attack generally begins from the buds at the tip of the inflorescence, as these being more hairy very easily catch the spores. Then it gradually extends on the flowerhead. Mildew also appears naturally on the tender vegetative shoots of the mango but the life history there is somewhat longer being about nine days.

In order to find out other hosts of the mildew, inoculations were also tried on *Bhendi* and *Guvar* leaves, but the mildew did not appear at all. The mildew spores retain their vitality for four to five days only and then shrivel up. If kept in the sun without any moisture, they shrivel up within four or five hours.

This mildew has been present on the inflorescences at Ratnagiri both in 1925-26 and 1926-27, but in both years it was not found on the first flush of flowers, but gradually increased in amount as the season progressed. In 1926-27 when very closed detailed observations were made, it mav be said that it was completely absent from the flowers until January 1927 and even from that time until February it was present only in verv small amount. The third flush in February and March was, however, very much attacked with it, and the variation in intensity noticed enables us to get some idea of the damage which it does. We may, in fact, compare the loss in the first flush (when neither hoppers nor mildew were present to any appreciable extent) with that in the third flush when mildew was verv much in evidence, and hoppers had almost disappeared. Twenty flowerheads were investigated in the former, and ten in the latter flush. The results were as follows :—

	Proportion of shed flowers	
	1st Flush	2nd Flush
	(Mildew absent)	(Mildew present)
Complete flowers produced and examined	2,151	852
Proportion	Per cent	Per cent.
a shed before fertilisation	53·5	61·5
b. shed after fertilisation	16·3	38·4
c of ripened mature fruit	0·28	0·12

Here we have, therefore, some, though not conclusive, evidence of the part which mildew takes in the loss of flowers and young fruits, for the proportion of fruits ripened per 10,000 flowers is reduced from 28 to 12 or by 43 per cent. The stage at which this increased loss takes place is better shown by the following figures, which

indicates the proportion of the *remaining* flowers and fruits after the previous loss has taken place which shed at the succeeding stage :—

—	1st Flush (Mildew absent)	2nd Flush (Mildew present)
Complete flowers produced and examined . . .	2,151	852
Proportion —	Per cent.	Per cent.
a. of complete flower shed before fertilisation .	53·5	61·5
b. of fertilised flowers shed before fruit is 0·4 cm. in diameter.	88·8	95·1
c. of fruit 0·4 cm. in diameter shed before 1·5 cm. in diameter.	77·0	75·0
d. of fruit 1·5 cm. in diameter shed before maturity	77·0	75·0

Thus it is quite clear that the loss due to mildew affects the flowers before fertilisation, and the fruits in the youngest stages. If these latter reach 0·4 cm. in diameter the mildew can do them no further harm. In the early stages it does seem to be a very important agent in increasing the loss of flowers and young fruits and so seems of great importance.

Direct experiments were also undertaken to determine the effect of the mildew, when introduced into bagged flowerheads, as described on page 227. The results on the flowerheads so treated (ten in number in 1925-26 and 40 in number in 1926-27) were compared with a similar number bagged but not inoculated, with the following results.

TABLE XVI.

Effect of inoculating flowerheads with mildew (Bagged heads).

—	Flowers shed per 100 complete flowers formed.		Ripe Fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
1925-26	Per cent	Per cent	Per cent
1. Inoculated with mildew	66·1	33·8	0·10
2. Not inoculated	54·0	45·8	0·22
1926-27 *First flush*			
1. Inoculated with mildew	87·9	12·1	No fruits.
2. Not inoculated	87·5	12·3	0·15
Second flush.			
1. Inoculated with mildew	85·6	14·2	0·12
2. Not inoculated	82·3	17·5	0·17
Third flush.			
1. Inoculated with mildew	91·5	8·5	No fruits.
2. Not inoculated	76·3	23·5	0·18

PLATE V.

Appearance of inflorescences with bad attack of the mango *jassid* hopper.

The uninoculated flower heads were not always entirely free from mildew, but they always, of course, had much less of the fungus present than the inoculated flower heads. In the first flush of 1926-27, mildew was entirely absent and in the second flush it was only present in very small amount on the non-inoculated heads.

These figures, resulting from intensive inoculation with the mildew, show the *possible* effect of the fungus in a really serious attack. Under these circumstances, it will be seen that, even excluding other influences causing loss of fruits, the mildew was capable of completely destroying the crop,– as occurred in the first and third flushes of 1925-27, or in other cases of reducing it by one third (second flush of 1926-27), or by more than one half (1925-26) in two separate cases.

Effect of insecticidal and fungicidal treatment.

The methods designed to keep off the attacks of the *jassid* hopper and the mildew above described have been already detailed (Page 226). They consisted of repeated sprayings with either Fish oil soap solution (against the hopper) or Bordeaux mixture (against the mildew) or with a mixture of both these.

The efficiency of these treatments was not complete. So far as the hoppers were concerned each spray with the fish oil soap solution completely destroyed any nymphs of the *jassid* hopper which were on the inflorescences at the time and either killed or drove away the adults which were present. Within three or four days, however,– when the insect was abundant,– a few nymphs were again noticed. This number tended to increase, and before the time of the next spraying, which occurred during the second flush at intervals of from eight to fifteen days, the nymphs were again fairly numerous on the flower heads. Naturally, as the inflorescence becomes more mature, it becomes more and more difficult for the insect to lay its eggs in the *rachis* and in the branches of the inflorescence, and so if spraying is vigorously done, repeatedly, when the flower heads are young, the number of nymphs ultimately found on the head is materially reduced. But, though the treatment was repeated so often, the flower heads were not maintained anything like free of the *jassid* hoppers during the flowering.

A similar position is found with regard to the mildew. The fungus attacks chiefly, if not entirely, the very young parts of the flower head at the tip of each branch of the inflorescence. If it is then sprayed with Bordeaux mixture, the mildew is killed, but rapidly reappears on portions of the inflorescences which are subsequently formed. So that fresh spraying is really required at very short intervals. So that the new growth may be protected before the mildew has time to attack it. This is not, of course, entirely possible and repeated sprayings at intervals of from seven to fifteen days is the best that is practicable. It must be recognised, however, that the treatment does not entirely prevent mildew but it certainly reduces it very largely.

The actual results of these treatments can be best judged by the figures obtained with treated flower heads in both 1925-26 and 1926-27. In the first year no hoppers

were found and hence the comparison in that year is as to the effectiveness of the treatments in preventing loss by mildew, or by other unrecognised causes which accompany it.

TABLE XVII.

Effect of treatments in presence of mildew only, 1925-26.

	FLOWERS SHED PER 100 COMPLETE FLOWERS FORMED		Ripe fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
	Per cent.	Per cent.	Per cent.
1. Without treatment	38·4	60·8	0·77
2. Sprayed with Bordeaux mixture	42·9	56·2	0·93
3. Sprayed with Fish oil soap solution	48·8	50·7	0·47
4. Sprayed with combined spray	49·1	50·6	0·23

When, therefore, these sprays are used in the presence of mildew, they all cause an increased loss of shedding before fertilisation and this would perhaps not be unexpected. The loss by shedding after fertilization proved itself greater wherever Fish oil soap solution was used. Taking the percentage of loss on the *actual flowers* fertilised, the figures of shedding were as follows :—

	Per cent.
1. Without treatment	98·7
2. With Bordeaux mixture	98·4
3. With Fish oil soap solution	99·2
4. With combined spray	99·4

The difference is not, however, very great, and the real cause of the difference in the number of fruits ripened is the difference in the loss before fertilization—except that the untreated flower heads, which lost relatively less before fertilization, had a larger loss after this had taken place.

In the second year (1926-27) there was practically no mildew on the second flush and hence we have merely to consider the effect of the spraying treatments in the presence of *Jassid* hoppers. This is shown in the following figures : –

Table XVIII.

Effect of treatments in presence of hoppers only, 1926-27.

—	Flowers shed per 100 complete flowers formed		Ripe fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
	Per cent.	Per cent.	Per cent.
1. Without treatment	62·6	37·2	0·24
2. Sprayed with Bordeaux mixture	72·5	27·3	0·24
3. Sprayed with Fish oil soap solution	69·5	30·1	0·39
4. Sprayed with combined spray	74·7	25·0	0·23

Here, therefore, when these sprays are used in presence of hoppers only, that is to say, when the insects are *partially* suppressed during the flowering -the effect of all the sprays still shows an increased shedding before fertilisation. It would seem, in fact, that all the sprays when used with flowers which have been weakened by the insects, cause a greater number to drop off before they are fertilised.

After fertilisation there is less shedding wherever the material (Fish oil soap solution) which is supposed to check the hoppers is used, as is shown by taking the percentage of loss of actual flowers fertilised as follows : -

	Per cent.
1. Without treatment	99·4
2. With Bordeaux mixture	99·1
3. With Fish oil soap solution	98·7
4. With combined spray	98·7

The increased shedding of the unfertilized flowers more than neutralises with the combined spray, the advantage gained with those fertilized and the young fruits. With the Fish oil soap solution only, the difference shows quite clearly in a considerable increase in the number of fruits ripening.

We can now consider the effect of the treatments in the presence of mildew only by studying the third flush of 1926-27, for at this time the hoppers had practically disappeared, while mildew was very severe. Under these circumstances, the following figures were obtained.

TABLE XIX.

Effect of treatments in presence of mildew only, 1926-27.

—	FLOWERS SHED PER 100 COMPLETE FLOWERS FORMED		Ripe fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
	Per cent.	Per cent.	Per cent
1. Without treatment	61·5	38·4	0·12
2. Sprayed with Bordeaux mixture	62·1	37·5	0·40
3. Sprayed with Fish oil soap solution	57·1	42·7	0·23
4. Sprayed with combined spray	62·5	37·5	No Fruits.

Under these conditions of high mildew attack, without the presence of hoppers, the treatments (except that with Fish oil soap solution, which cannot at present be accounted for) seem to have had little effect on the loss before fertilisation. If any thing, the amount of loss at this stage was increased as in the previous cases.

After fertilisation, there is distinctly less shedding with the treatment with Bordeaux mixture, which was used specifically to check the mildew, as is shown by taking the percentage of loss of *actual flowers fertilised*, as follows :—

	Per cent.
1. Without treatment	99·7
2. With Bordeaux mixture	98·9
3. With Fish oil soap solution	99·5
4 With combined spray	100·0

The checking of the fungus attack, when this latter was very active, has led in fact to raising the proportion of fertilised flowers which come to maturity by a substantial amount. The number has been raised to three times that in the untreated flowers heads. The fish oil soap solution, whether alone or as a combined spray, has been of much less use, and in the latter case the *whole* of the fertilised flowers fell without forming fruits.

These figures show very clearly the very important part played by mildew, when it is present, in causing the fall of flowers, and particularly of fertilised flowers and very young fruits. But it is equally obvious that it is not, by any means, the chief cause of the fall even of fertilised flowers and young fruits, -and while it may reduce the crop from a flush to one third its normal amount, there is an enormous shedding to account for, independently of any mildew attack.

But this extra loss due to mildew is of very great importance, and may obviously make all the difference between a profitable flush and one which is a financial failure.

So far the treatments described were applied to a number of flowerheads which were separately kept under observation. But at the same time, the treatment with Fish oil soap solution was applied to whole trees, half the tree in each case being kept unsprayed. We can thus compare the number of ripened fruits per hundred flowerheads on the two halves of the same tree, and thus get a reliable measure of the effectiveness of the treatment. The results were as follows, the trees being sprayed as frequently and at the same times as described on page 226.

TABLE XX.

Effect of spraying whole trees on fruit ripening.

	Number of flower heads on half tree	1926-27		
		Number of fruits obtained on half tree	Number of fruits per 100 flower heads	Percentage increase by treatment
1st tree.				
1. Unsprayed	956	197	20·6	.
2. Sprayed with Fish oil soap solution .	588	152	25·8	25·4
2nd tree.				
1 Unsprayed	784	225	28·7	..
2 Sprayed with Fish oil soap solution .	430	141	32·8	14·3

Other tests made by spraying some trees in a garden and comparing them with unsprayed trees in the same garden gave an increase of fruits 31·9 per cent. and 25·0 per cent., respectively. But too much stress should not be laid on these figures, as trees differ so much in their individual capacity to bear. Enough has been found, however, to show that by spraying in the manner suggested through the hopper season at Ratnagiri, the number of ripened fruits can be increased by from 11 to 25 per cent. and possibly by more than this amount.

INFLUENCE OF OTHER FACTORS ON MANGO FLOWER AND FRUIT SHEDDING.

As already stated, the popular idea is that the loss of mango flowers and young fruits is much increased by cloudy, wet, or dewy weather during the flowering season. Hence an attempt was made to see how the fall of flowers and young fruits was affected by excluding any rain or dew which might fall on the inflorescences. To do this, five flower heads during 1925-26, and ten flower heads during 1926-27 were protected above with a glass plate, so that any moisture falling on them from above was excluded.

Only the records for 1926-27 have been kept completely. In this year a full record of the rain and dew was maintained. Dew was common in February and March, but no rain fell throughout the flowering season. The performance of the protected flowerheads as compared with controls either on the same trees or in the immediate neighbourhood was as follows: –

TABLE XXI.

Shedding of flowers and young fruits protected from rain and dew.

	Number of complete flowers	Flowers shed per 100 complete flowers formed		Ripe fruits per 100 complete flowers
		Shed before fertilisation	Shed after fertilisation	
		Per cent.	Per cent.	Per cent
1. Without protection	2,151	53·5	16·3	0·28
2. Protected with glass covers	2,137	69·8	29·9	0·28

Thus, from these figures, it will be seen that the final production of ripe fruits was not altered by the protection given. The presence of the cover seemed to reduce the number of *fertilised* flowers and young fruits which were shed, but, on the other hand, tended to increase the shedding of the flowers before fertilisation. There is, however, no evidence that under the conditions of the last season, such protection as that given was of any great advantage. This is in agreement with results obtained by Popenoe[1] in Florida.

The only other cause of the variation in the shedding which has been suggested is the want of assimilated plant food and possibly also of water, and attempts have been made in both the seasons under record to ascertain whether the application of irrigation during the flowering season to trees, or the addition of concentrated manures applied in trenches round the trees, made a very substantial difference to the yield of fruits per 100 flower heads. The results in both cases are, the author feels, vitiated because of the very large variation from tree to tree in all cases. It is true that, on the average, each of these treatments, with irrigation or with concentrated manures, raises the number of fruits produced per 100 flower heads. Thus, in 1926-27, taking the record of three trees, irrigation raised the number of fruits per 100 flower heads

[1] Popenoe, W. Manual of Tropical and Sub-Tropical Fruits, 1920.

from 29 to 37, but the actual number of fruits per 100 flower heads were in each of the three cases

1. Irrigated trees . . . . 15, 21 and 14
2. Unirrigated trees . . . . 11, 20 and 27

So that it is very doubtful whether the difference is due to the irrigation at all. Similar vitiation of the results has been the case in those trees where concentrated manures have been used, and we are compelled to leave further investigation of the matter to the next year.

General conclusions.

The author feels that the results of this investigation, so far as they have gone, have emphasised the very great loss even of complete flowers, which normally takes place in mango flowering. That loss, including the cases where the flowers fall before fertilisation and those where young fruits are shed, amounts normally, with the Alphonso variety of the mangoes at Ratnagiri, to over 99 per cent. of the complete flowers formed. In some years, as in 1926-27, the loss was in all cases substantially over 99·5 per cent.

So far as almost the whole of this loss is concerned, the investigations made have so far not revealed any cause for the falling of the flowers and fruits. Only a very small proportion of the flowers in certain flushes, at any rate, showed any recognisable outward symptoms which would have suggested that they were likely to fall. These recognisable causes were mildew and certain black spots on the flower and fruit stalks and on the fruits, the nature of which was not identified. But both these classes of symptoms were present in so small a proportion of cases, that it is evident that they were very minor elements in causing flower and fruit shedding in the mango.

The cause of by far the largest proportion of the loss of mango flowers and young fruits, therefore, remains a mystery. But there are two clear causes which are able to affect very materially the quantity of fruits, small though it be, which actually ripen. So far as the experiments show, the presence or absence of rain or dew is not one of these, though this matter still needs further investigation. But the well known *Jassid* hopper, the chief species of which at Ratnagiri is *Idiocerus niveosparsus*, and the mango flower mildew, which belongs to a form of *Erysiphe* which has not been fully studied, both affect very materially the proportion of complete flowers which ripen into fruits.

At Ratnagiri, however, the first flush of flowers in November and December seems normally free or nearly free from both these enemies, the second flush in January and early February usually has abundance of hoppers and a small amount of mildew, while in the third flush in late February and March, the hoppers are much less abundant, but the mildew tends to get worse and worse. In some years, as in 1925-26, the hoppers were very rare throughout the season.

Any attempt to check these two enemies by spraying, even repeatedly and at short intervals, has been only very partially effective in keeping the flower heads free of them. The reinfection of inflorescences which have been cleared of hoppers by fish oil soap solution was almost immediate and as the greater part of the damage is done by the nymphs, they were able to affect the flower head materially before the next spraying took place. In the case of mildew, the attack takes place by preference on the portions of the inflorescences as they appear, that is to say, on the youngest portion. The result is the relative inefficiency of the spraying treatment, even frequently repeated against this also.

But three things seem clear from the study of treatments by spraying. The first is that all of them cause, whether the pests and blights are present or not, an increased loss of unfertilised flowers, though they may lead to a reduction in the amount of fall in flowers after fertilisation. In the absence of disease, the total effect of the sprayings is negligible.

The second is that the spraying with Bordeaux mixture has been effective in increasing the percentage of success in ripe fruits when mildew is present by 21 per cent. in 1925-26 and by 230 per cent. in 1926-27. In presence of mildew (hoppers being absent), spraying with fish oil soap solution seemed distinctly harmful in 1925-26, while the result was doubtful in 1926-27.

The third result is that, in presence of hoppers spraying with fish oil soap solution increased, in the flower heads under detailed examination, the yield of ripe fruits by 62 per cent. in 1926-27. A combined spray of Bordeaux mixture and Fish oil soap solution was not effective even against hoppers.

The work will be continued in the next two seasons, with the chief object of, on the one hand, finding an effective method of controlling the hoppers and mildew under the conditions of attack which have been described, and, on the other, of trying to trace further the cause of some at any rate of the loss of complete flowers which leads, at present, even under the most favourable circumstances to a shedding over 99 per cent. in the principal commercial variety of mango at Ratnagiri.

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APPENDIX I.

The composition of forty mango inflorescences in 1925-26.

Serial No.	Total No. of flowers	Male flowers	Complete flowers	Percentage of complete flowers
1 . . .	550	313	237	43 09
2 . . .	1,147	919	228	19·7
3 . . .	2,823	2,432	391	14·5
4 . . .	600	344	256	42·66
5 . . .	492	432	60	12·13
6 . . .	3,549	3,307	242	6·81
7 . . .	1,195	991	204	17·07
8 . . .	1,186	957	229	19·30
9 . . .	338	309	29	8·58
10 . . .	789	593	196	24·84
11 . . .	3,129	2,867	262	8·37
12 . . .	1,555	1,015	540	34·72
13 . . .	508	327	180	35·43
14 . . .	2,540	2,470	70	2·75
15 . . .	2,080	1,975	105	5 04
16 . . .	970	734	236	24·33
17 . . .	56	25	31	55 35
18 . . .	369	304	65	17·04
19 . . .	354	190	164	46·32
20 . . .	147	144	3	2·04
21 . . .	151	98	53	35·08
22 . . .	206	138	68	33·00
23 . . .	834	565	269	32·13

The composition of forty mango inflorescences in 1925-26—contd.

Serial No.	Total No. of flowers	Male flowers	Complete flowers	Percentage of complete flowers
24 . . .	282	240	42	14·80
25 . . .	279	161	118	42·29
26 . . .	971	855	116	11·9
27 . . .	502	249	153	30·47
28 . . .	1,599	945	654	40·9
29 . . .	518	233	285	55·01
30 . . .	2,454	1,838	616	25·0
31 . . .	573	499	74	12·09
32 . . .	1,584	1,138	466	29·4
33 . . .	481	415	66	13·74
34 . . .	959	868	91	8·48
35 . . .	448	298	150	33·48
36 . . .	20	15	5	25·0
37 . . .	917	829	88	9·59
38 . . .	2,096	1,591	505	24·09
39 . . .	663	402	261	30·9
40 . . .	1,465	1,046	419	28·60

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Memoirs of the Department of Agriculture in India

Studies in the Jowars of Gujarat

I. The Jowars of the Surat District

BY

M. L. PATEL, M. Ag.
Cotton Breeder, South Gujarat, Surat

AND

G. B. PATEL, B. Ag.
Assistant for Jowar Breeding, Surat

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STUDIES IN THE *JOWARS* OF GUJARAT.

I. THE *JOWARS* OF THE SURAT DISTRICT.

BY

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AND

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Assistant for Jowar Breeding, Surat.

(Received for publication on 17th October 1927.)

INTRODUCTORY.

The sorghum or *jowar* crop is, with the solitary exception of rice, the most important of all those cultivated in India. In the Bombay Presidency it stands easily first of all, and if we include Sind, its annual area approaches eight million acres. In the Bombay Presidency proper, its cultivation reaches $6\frac{1}{2}$ million acres annually. Of this enormous area, the British Districts of Gujarat claim only a little over 8 per cent., and yet in all of these Districts (except Kaira and the Panch Mahals) the *jowar* crop is one of very great importance.

In the Surat District which represents the southern extremity of the Gujarat *jowar* area, almost the whole of the crop is grown in the *kharif* season, and its distribution is shown in the following Table of area by talukas (based on the record of 1922-23).

TABLE I.

Distribution of Jowar in the Surat District.

Taluka	Area 1922-23	Proportion of cropped area
	Acres	Per cent
Chorasi	15,705	28·2
Olpad	22,862	18·2
Mandvi	19,062	16·6
Bardoli	19,451	13·9
Jalalpur	12,778	15·9
Chikhli	3,209	3·2
Bulsar	67	0·0
Pardi	10	0·0

The Surat District, as will be seen from the above table, clearly passes out of the typical *jowar* region in the south where the rainfall is too high for its cultivation to prevail, and where it is replaced by rice. In the more northerly parts of the District, with a rainfall of 40 inches, all received between the months of June and October, and with a heavy black soil, there appears a region particularly suitable for this crop, and especially for the varieties which have a long period of growth, yield highly, and give also long and heavy straw. In fact, the types of *jowar* commonly grown in Surat are among the latest (that is to say, they have the longest period of growth) in India. They ripen in from four to six months. The varieties grown differ, however, very markedly in this respect, and thus vary in their suitability for growth according to the character of the season.

In the Surat District, *jowar* is always rotated with cotton, and its sowing is generally delayed until the cotton has been planted. If the land becomes foul with weeds during this period, it is ploughed and harrowed before sowing. The delay is necessary, for if *jowar* be sown at the beginning of the monsoon, it is always very severely attacked by one of the borers (*Chilo simplex*, *Sesamia inferens* or the anthomyid fly borer). It is usually sown by drill in rows two feet apart in the middle of July in heavy black soils, while in lighter soils it is put in a little earlier. After four to five weeks, the crop is thinned to a distance of one foot between the plants. The seed rate used is five to six pounds per acre, and it is often sown mixed with two to two and a half pounds of *Cajanus indicus*) and a few ounces of *mung* (*Phaseolus mungo*) and *charli* (*Vigna catiang*). During the younger stages of the growth the most serious danger lies in the attack of the borers mentioned above, which begins from two to three weeks after germination and is particularly serious in a year of heavy and continuous rain. As a result, it is wise to sow thickly and to thin out the affected plants. Inter-cultivation is given with the blade harrow.

The crop grows very vigorously from September, that is to say, from eight weeks after sowing, and the earheads appear from the last week in October. Absence of rain in September is injurious, but rain in October is believed to give small ear heads and reduce yield : north-east winds in December hasten the ripening.

Reaping is done in January when the topmost leaf (flag) dries up and turns yellow, and is started early in the morning (5 a.m.), when there is dew, to avoid dropping of leaves. The bundles are arranged in conical heaps in the field for drying and then the earheads are cut off, carried to the threshing yard, dried for a few days and threshed. The average yield per acre is 720 lb. of grain and 1,200 lb. of dried fodder.

The main enemies of the crop are the borers afore mentioned, which, at Surat as tested near the end of October, have given a percentage attack as follows in four successive seasons.

1922-23	72 to 87	per cent.
1923-24	20	„
1924-25	65	„
1925-26	47	„

Jowar Varieties of the Surat District.

The varieties of *kharif jowar* generally grown in the Surat District are five in number. Of course, there are a number of minor types grown in odd places but those of which a short description is now to be given comprise all that are at present of any practical importance. These are :—

1. *Perio Jowar.*

This is the main variety grown in the Surat District, occupying more than three-fourths of the total area. It is also called '*bhar*' or '*deshi*' and its characteristic feature (from which it takes its name) is the pearly yellow colour of the grain. It varies very much in the character of the plant and especially in the character of the earhead. Thus there are types known as *Fafar* with loose earheads, generally consisting of tall plants with long peduncles and erect heads, liable to lodge and usually with low yield. Other types are known as *Budh perio* with compact heads, usually possessing short and thick internodes on the stems. Another kind is known as *Moni Timberwa* or *Deshi* with larger though softer grain than ordinary *Perio jowar* bringing a higher price. The heads in this kind vary considerably in compactness. A fourth type is *Perio Sholapuri*, intermediate between the Perio and Sholapuri varieties. And finally, there is *Agio jowar*, a kind resistant to the *striga* pest, sometimes known as *Khaplatio Nialo*, largely consisting of white ribbed plants, said to ripen early even when sown late.

From this description it will be seen at once that the so-called *Perio jowar* is a mixture of types, whose almost only connection is the pearly character of the grain. To take only one or two characters as tests. It was found that there is a very clear distinction between plants with a green midrib of the leaf and plants with a white midrib. The latter always have a pithy stem. In 1924-25 a sample of local *Perio jowar* seed gave 55 per cent. of green midribbed and 45 per cent. of white midribbed plants. In 1926-27 various samples gave 55·5, 82·0, 95·0, and 64·3 per cent. of green midribbed plants respectively. A type mass selected on the Surat Farm for a number of years gave 96·6 per cent. of green midribbed plants.

Another difference, easily recognisable is in the colour of the anthers after weatheration. Surat Farm selected *Perio jowar* in 1922-23 gave 93·0 per cent., and in 1926-27 gave 95·7 per cent. of red anthered plants. Local *Perio jowar* in 1925-26 gave only 35·0 per cent. and in 1926-27 gave 39·7 and 42·0 per cent. of red anthered plants. A lot of seed known as *Agio jowar* gave, in 1926-27, 37·6 per cent. of red anthered plants.

Judged by either of these very simple tests, the extreme heterogeneity of the material grown under the name of *Perio jowar* in Surat is very apparent.

2. *Sholapuri Jowar.*

Nothing is certainly known as to the origin of this type of *jowar*, but it is commonly believed that it was introduced from the Deccan either during or after the

famine of 1899-1900. Its main characteristic is that it can be sown later than the ordinary types, and it ripens earlier and gives a large yield. It grows quite wel if planted in September. It occupies one-eighth of the total *jowar* area in Surat The fodder is largely pithy (the plants having a white midrib) and is thus poor. An actual field examination in 1925-26 gave 99·3 per cent. of white midribbed plants It is said to do well in the lighter soils or on sloping black soils, where less wate is retained. It is apt to lodge, more than any other of the local types. The earhead is nearly always loose, and is distinctly conical when it first appears (Plate I The anthers are very rarely yellow in colour, but brown and red anthered type are common.

3. *Chapti Jowar.*

This variety is grown to a limited extent on highly retentive *besar*, or alluvia clay soils. It thrives under heavy rainfall conditions. The grains are very large fiat, soft and white, and so bring about Rs. 7 to 8 more per *galli* (1,140 lb.) than th *Perio jowar*. The grains being soft and mealy are, however, easily attacked by weevils. The earheads are all semi-compact. The chaff is small in amount. The fodder is preferred for softness.

This variety also includes many varying types. The best known as *Telia-chapt* is grown in Baroda territory near Bardoli and Nior, and brings from Rs. 10 to 1 per *galli* more than ordinary *Perio jowar*. In this variety plants with white midril are very scarce, and thus the straw (*Kadbi*) is very highly valued. Types with re or brown anthers are found varying from 1·8 per cent. of the plants on the Sura farm to 1·8 per cent. in the ordinary crop.

4. *Nialo Jowar.*

This jowar is a type which can be planted late, say in August, September or eve up to the middle of October. It is often sown in fields where rice would normall be planted, but where rice cannot be grown owing to a dry season. When put in in October, it grows quickly, flowers within sixty days, and yields a good crop It is, however, more especially useful as a fodder variety and does not grow ver tall. The earheads are always loose on long straight peduncles.

The plants of this variety bear only six to eight small leaves, and are thin stem med, and its area fluctuates much from year to year. It is said to be largely immune to the striga pest. Almost all the plants have red or brown anthers, some sample giving nothing else, while one field counted gave 93·2 per cent.

5. *Vani Jowar.*

This is a type of *jowar* used for parching in the green condition, and is often grown simply as a few rows in a field. The colour of the ripened grain varies, however very widely, but the wrinkled seeds, pitted at the tips, are very characteristic The ripened grain is somewhat flinty.

The leaves in this variety are generally very erect and the midribs are generally white.

Typical samples of the grain of four of these varieties gave the following figures on analysis

—	Budh Perio	Chapti	Sholapuri	Vani
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	11·7	11·8	11·4	11 0
Ether extract	3·1	2·7	3·6	4·3
Albuminoids	8·2	6·5	6·5	10·5
Digestible carbohydrates	74·4	76·1	75·9	69·8
Woody fibre	1·3	1·2	1·1	2·4
Ash	1·3	1·7	1·5	2 0
	100·0	100·0	100·0	100·0

To the north of the Surat *jowar* area, lies the large *jowar* growing area of Broach, but in this latter District the jowars cultivated are almost all *rabi jowars*. These latter can be readily distinguished, even in appearance by the fact that the leaves are completely glabrous, that the leaf sheath does not completely cover the internode, that the midrib is always green, that the earheads are usually very highly compact, that they ripen much more rapidly than either *Perio*, *Chapti*, or *Sholapuri* and that they are very much less liable to weevil attack than the *kharif jowar* of Surat. The seeds are generally smaller and lighter than those of the *kharif* crop.

Among the Surat varieties themselves, the most obvious differences are :—

(*a*) The difference in colour of the midrib (green and white), the latter indicating a pithy stem. *Sholapuri*, Vani and *Khaplatio-Nialo* have white midribs; *Chapti* has green midribs; *Perio* has both in varying quantity.

(*b*) The difference in size of plant :– *Nialo* is a small plant with few small leaves.

(*c*) The difference in hairiness of leaf :– *Chapti* is a less hairy type, especially near the midrib of the leaves.

(*d*) The difference in compactness of earhead :—All stages of compactness are found in *Perio*. In *Chapti* all are semi-compact, while in *Sholapuri* and *Nialo* the earheads are generally loose.

(*e*) The difference in length of the peduncle :—This being longer in *Sholapuri* and *Nialo* than in *Budh-perio* and *Chapti*.

(*f*) The difference in anther colour :—This varies much in all varieties bu in *Sholapuri* and *Nialo* red and brown anthers are found in by far th majority of cases.

(*g*) The difference in grain size and colour :—This has been already described

Almost all these differences, except those of colour, are differences of degre

Botanical Characteristics of the Jowar Plant.

In the present section, it is proposed to take a number of the botanical feature of the *Jowar* plant, and consider the variations which occur in them, as illustrated b the *Jowars* of the Surat District.

Stem. In a normal season, all the three main Surat *Jowar* varieties—*Peru Chapti, and Sholapuri*—have from seven to twenty-two nodes, the total height varyin from 60 to 220 cm. with an average of about 150 cm. The *Sholapuri* variety i not so tall as the others owing to a smaller number of nodes, but on the other hand the upper nodes are usually longer in this case.

The *Jowar* plant has a series of short internodes at the base, has the longes internodes in the middle of the stem, while the top internodes are generally longe than those at the base but not so long as those in the middle. If, however, th crop in Surat is sown very late, say in September, then the top-most internode (say five in number) tend to be the longest, the middle ones standing next.

In all the standard Surat varieties the maximum internodal circumference o the stem is 2·5 to 4·3 cm., with a diameter of 1·2 cm. In very early flowering types the stem is always thin.

Leaves. The leaves occur in two opposite ranks, and are acute at the apex broadest above the middle, somewhat narrowed at the base. The fourth lea from the top represents, fairly closely, the average leaf. The length in the Surat varieties varies from 10 to 60 cm., and the greatest breadth from 5·4 to 8 cm.

Some types of *Jowar* have the leaves almost completely glabrous. Others are very hairy. The hairiness is most seen in the upper half of the leaf, though when the leaf is fresh, it is seen all over the lower half of the ventral surface. In *Chapt jowar* there is the curious variation that at the tops of the leaves the hairiness (Plate VI) is emphasised near the midrib, while this is not the case as one proceeds towards the base, and the hairs get sparse on both halves. In *Perio jowar* hairines is far more evenly distributed over the two halves of the leaves.

What purpose the hairs serve is quite unknown. By many workers they have been claimed as a means of drought resistance, but the evidence for this is very slight. The hairs can best be seen with a lens when the flag of a leaf is just out, between 9 and 11 a.m. As the leaf gets older, the hairs drop off. On the ligule, there is always a thick mass of long hairs.

On the leaf sheaths, there is generally found a deposit of wax, in the case of the upper four or five leaves, but the amount of this deposit is very variable. It is

extremely developed on one of the pure strains which the authors have isolated (*Althan Deshi* 6) to be afterwards described. What its purpose is, is very doubtful. Haberlaudt[1] considered it as a means of increasing the effectiveness of the control exercised by the epidemis on transpiration. In the case of wheat, on the other hand, Bhide[2] has claimed that absence of wax and capacity for vigorous growth were positively correlated. In the case of *Jowar* at Surat, the wax was found to have a specific gravity of 0·893 at 26·5° C. and had a melting point of 83° to 85° C. It darkened much on melting. It was soluble in ether, but practically insoluble in alcohol, benzene, or chloroform. As scraped from the plants, it gave 9·25 per cent. of ash.

The Inflorescence. The *Sorghum* or *Jowar* inflorescence is a panicle, usually called the head. The heads differ widely in shape. The central axis is usually angular, and the side branches are in apparent whorls. The lower branches in the panicle are, however, irregularly arranged, and only about an inch from the bottom do regular whorls appear. The distance between the whorls is usually greatest in the middle of the earhead.

On the panicle branches, the spikelets usually occur in pairs or occasionally in threes; towards the tips of the branches and branchlets, they almost invariably occur in threes. Invariably, one of the two or three is sessile and hermaphrodite, while other one or two, as the case may be, are pedicelled and either empty or staminate. The sessile or hermaphrodite ones are broad, thick and fertile; the pedicelled ones are narrow and long.

In an average season the fertility of the earhead in Surat *jowar* is very nearly complete, except for a few failed flowers at the base of the earhead. These may be taken at 10 to 15 p.c. of the total heads as a rule. In some years, however, a larger failure occurs, and one such year was 1926-27 when the percentage of failure rose to 15 to 20 per cent. of the heads. A detailed examination of heads of two pure types of *Perio jowar* (*Althan Deshi* 6 and *Budh-perio* 53) was made, with the following results.

Althan Deshi 6.

(1) *Normal main shoots.* (15 earheads with such failures examined) Nearly 60 per cent. of the earheads had patches of failed flowers at the base, say within one inch of the bottom; 22 per cent. had similar patches in the lower half of the heads; 18 per cent. had patches of failure right even to the top, though their frequency increases when descending the ear.

(2) *Shoots from stubbles and tillers.* (10 earheads examined) The base only was affected in 13 per cent. of the cases; 22 per cent. had similar patches on the lower half only; nearly 65 per cent. had patches of failure all over the earhead.

(3) *Shoots from axillary branches.* (20 earheads examined) The flowering of these shoots was late. There were no cases where the failure was limited to the

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[1] Haberlaudt. Physiological Plant Anatomy, page 107.
[2] R. K. Bhide, *Annual Report, Bombay Department of Agriculture* 1920-21, page 118.

base or lower half of the earhead, but 35 per cent. of the earheads had small patches of failure all over.

Budh-Perio 53.

(1) *Normal main shoots.* (10 earheads with such failures examined) Nearly 5 per cent. of the earheads had patches of failed flowers at the base; 25 per cent had such patches in the lower half; and nearly 20 per cent. had patches all over.

(2) *Shoots from tillers and stubbles.* (40 earheads examined) The base only was affected in 35 per cent. of cases; 15 per cent. had similar patches on the lower half only; 50 per cent. had patches of failure all over the earhead.

(3) *Shoots from axillary branches.* (20 earheads examined) The heads of these shoots showed 20 per cent. with small patches all over the earhead.

The only clear indication from this examination is that failure on the lower part of the earheads is more likely to occur than in the upper; though the percentage of non-fertilized flowers in such heads is low, *viz.*, 1 to 4 only.

Glumes. The lemmas of the fertile flowers in the Surat varieties of *jowar* have awns, while the staminate or empty flowers are awnless. The awns attached to the lemmas of fertile flowers in different varieties were measured from one hundred spikelets and showed an average length of 1·13 cm. with *Chapti jowar*, and 1·1 cm. with *Sholapuri jowar*. *Vani jowar* gives figures very close to those for *Chapti jowar*. The awns in *Perio jowar* are much shorter, 100 flowers of *Budh-Perio* giving 0·84 cm. as the mean awn length. There appear to be characteristic differences in the variation of the outer glumes. In *Chapti jowar* there is an average of 11·5 veins per glume; in *Budh perio* 10·6 veins and in *Sholapuri* 9·6 veins. In the *Budh-perio jowar* the veins extend to the edge, and are clearly marked at the top of the glume and the glumes are very hairy; in *Sholapuri* the veins extend further downward, but the glumes are much less hairy; while in *Chapti* the veins almost reach the base of the glumes and the latter are still less hairy than with the *Sholapuri* type.

In shape the outer glumes are roundish at the top, and broad in relation to length in the *Perio* type; in the *Sholapuri* kinds they are more tapering and relatively longer. The *Chapti jowar* has glumes longer than the *Perio* and broader than the *Sholapuri* types.

Coloration of the anthers. When the grains begin to ripen, the anthers are seen on the earhead in a shrivelled condition after weatheration. Well marked colour differences can be found in this condition in different varieties and strains. In all there are two main divisions of this anther colour, that is to say, the anthers are either yellow or red, though the shade of each varies a good deal. This character is very important in recognising different strains of a variety, and the following notes were made in 1923-24 and 1924-25 by one of the authors.[1]

[1] Patel, G. B. Extent of natural cross-fertilization of *Jowar* at Surat *Agricultural Journal of India* Vol. XXI, page 366.

"In 1923-24 the seed obtained from mother earheads with red anthers either gave entirely flowers with red anthers, or else flowers with red and yellow anthers in a proportion of 2·9 to 5·3 to 1. When the mother plant had yellow anthers, the progeny bred true in this respect. This latter observation was confirmed in 1924-25, but again some red or brown anthered plants gave very variable results, red or brown anthers being more numerous than yellow in a proportion which varied from 1·7 to 4·1 to 1."

The relationship of colours of anthers to colour of stigma was studied in 1926-27. In the case of a strain of *Budh-perio* marked No. 53, which is a red-anthered type, eighty-five plants were examined in this connection. Out of these 9 had light brown anthers and 76 had distinctly red anthers. All the distinctly red anthers had also the shrivelled up stigma of a red colour. The nine plants with light brown anthers had light coloured stigma. A similar association of colours was found with plants of the *Sholapuri* type and with other strains of *Budh-perio jowar*. In the case of yellow anthered types the stigma is likewise whitish yellow to yellow in colour.

Variation in the number of pedicelled staminate flowers. It has already been noticed that the spikelets usually occur in pairs or in threes, one of which is sessile and hermaphrodite and the others are pedicelled and either empty or purely staminate. The interest in these staminate flowers was increased by the discovery of a great variation in the amount of cross pollination. The question arose, in fact, how far the proportion of such staminate flowers varies from strain to strain and how far this variation has anything to do with the extent to which cross-pollination takes place. A single earhead of seven different strains, grown in pure condition for several generations, was dissected, and the relative proportion of different types of flowers determined in 1926-27. The results are shown in the following Table :—

TABLE II.

Variation in the number of staminate flowers.

—	Strain and variety						
	Althan Deshi 6	*Budh Perio* 9	*Mori Timberera* 7	*Budh Perio* 40	*Chapti* 8	*Sholapuri* 21	*Sholapuri* 1
Hermaphrodite flowers per head . .	2,354	1,846	1,459	1,918	1,116	1,725	2,387
Pedicelled flowers per head . . .	3,242	2,345	1,894	2,443	1,506	2,261	3,082
Proportion of pedicelled to hermaphrodite flowers.							
(Hermaphrodite flowers-1) . . .	1·38	1·27	1·30	1·27	1·34	1·31	1·30
Proportion of hermaphrodite flowers with *one* pedicelled flower attached, in percentage.	60·2	68·3	64·8	67·1	58·8	67·7	68·5
Proportion of hermaphrodite flowers with *two* pedicelled flowers attached in percentage.	38·7	29·4	32·5	30·2	38·1	31·6	30·3
Proportion of hermaphrodite flowers with *no* pedicelled flower attached to it, in percentage.	1·1	2·3	2·7	2·7	3·1	0·7	1·2
Proportion of pedicelled flowers which have anthers in percentage.	40·0	23·5	19·4	3·4	0·9	0·2	0
Proportion of pedicelled flowers which are empty, in percentage.	60·0	76·5	80·6	96·6	99·0	99·8	100

It will be seen from the above analysis that the importance of the pedicelled, staminate— flowers is very different in different varieties and strains. The first three strains in the table, *Althan Deshi 6*, *Budh Perio 9* and *Moni Timberua 7*, are all compact headed types, though *Budh Perio 9*, is less compact than the other two. *Budh-Perio 40* and *Chapti 8* are what may be called semi-compact types, while the earhead of the *Sholapuri* strains would be classed as loose. It is at once clear that the compact types all of which belong to the *Perio* variety have a very much larger number and proportion of pedicelled flowers with anthers, or, in other words, of staminate flowers. In the case of the *Chapti jowar* type examined, and also of the semi-compact type of *Perio* the number of genuine staminate flowers is very much less, while with the loose *Sholapuri* types there are hardly any of them. This is not due to the absence of pedicelled flowers because the *Sholapuri* types have almost as many of these as any, the lowest number being in the *Chapti jowar*. The proportion of pedicelled flowers to hermaphrodite flowers varies from 1·27 to 1 to 1·38 to 1.

It will also be noticed that between 59 and 68·5 per cent. of the flowers are arranged in pairs, one flower of the pair being hermaphrodite and one pedicelled. The proportion does not vary very much from strain to strain. The remainder of the flowers almost all consist of groups of three, consisting of one hermaphrodite and two pedicelled flowers. Complete hermaphrodite flowers without any pedicelled flowers attached only occur in a limited number of cases never exceeding 3·1 per cent and going down in certain cases (*Sholapuri 21*) to under 1 per cent. There is one other interesting feature which comes out from this analysis of the flower conditions in heads from a number of pure strains of *Kharif jowar* at Surat. This is as to the kind of flower group in which the genuine staminate flowers occur. The following figures show this :–

TABLE III.

Place of occurrence of staminate flowers.

—	Pedicelled flowers per head	Staminate flowers per head	Hermaphrodite flowers with 1 staminate flower	Hermaphrodite flowers with 2 pedicelled flowers	
				(*a*) *Both* pedicelled flowers with *anthers*	(*b*) *one* pedicelled flower with *anthers*
Althan Deshi 6	3,242	1,291	544	85	577
Budh Perio 9	2,345	551	229	40	242
Mori Timberua 7	1,894	367	189	17	144
Budh Perio 40	2,443	84	39	5	35
Chapti 8 . . .	1,506	13	none	none	13
Sholapuri 21.	2,261	4	2	none	2

It will be seen that in all the types except *Chapti* there is about an equal probability of genuine staminate flowers occurring in association with a hermaphrodite flower as a pair, and as *one* of two pedicelled flowers in association with a hermaphrodite flower in *Chapti* also. It is comparatively rare for both the pedicelled flowers in a group of three to contain anthers.

In this connection, it is interesting to observe that in all cases except in some measure in *Althan Deshi* 6 and *Budh Perio* 9, the upper portion of the earhead and the tops of each branchlet contain a larger proportion of genuine staminate flowers, particularly the double staminate ones than the rest. In the two types mentioned the distribution is fairly uniform.

TABLE IV.

Distribution of staminate flowers in earhead.

——	*Althan Deshi* 6	*Budh Perio* 9	*Moni Timberua* 7	*Budh Perio* 40	*Chapti* 8
Proportion of staminate to pedicelled flowers in per centage —					
At the tops of panicle branches . .	41·7	50·6	55 1	64 3	100 0
In the upper one-third of panicle—					
(*a*) all flowers included . . .	17·4	24 5	41·4	58·3	84 6
(*b*) in groups with two pedicelled flowers	31 7	55 0	94·1	100·0	none
(*c*) in groups with one pedicelled flower	15 2	19 3	36·0	52·7	84 6

The question thus arises as to the part which these staminate flowers play in the pollination and fertilization of the hermaphrodite flowers in the ear. To investigate this matter, a study of the progressive development of flowering on individual earheads was made.

Progressive development of flowering. The number of flowers opened each day was counted before any opening began in the following morning. The flowers in the earhead to open first are the hermaphrodite ones, and a few of these usually open before the earhead is completely out of the sheath (specially when grown on ridges or when the *Jowar* is drying up) and those at the top of the head are almost invariably the first to open.

The date at which the flowering started and the number of days needed for all male and hermaphrodite flowers on the same heads was recorded for a number earheads in 1922 and in 1926, with the following results :—

Variety and strain	Hermaphrodite flowers		Male flowers	
	Date of opening of first *flower*	Number of days to complete *flowering*	Date of opening of first *flower*	Number of days to complete *flowering*
Althan Deshi 6	..	..	..	..
1st earhead	Dec. 6, 1926 . .	9	Dec 9, 1926 . .	9
2nd earhead	Nov. 23, 1926 .	11	Nov. 27, 1926 .	10
3rd earhead	Nov. 22, 1926 .	12	Nov. 25, 1926 .	13
Budh Perio 9	Nov. 16, 1922 .	11	..	..
Budh Perio 40	Dec. 7, 1926 . .	9	Dec. 10, 1926 .	8
Chapti 8	Nov. 20, 1922 .	10	..	..
Sholapuri 1	Nov. 24, 1922 .	9	..	..

It will at once be seen that the hermaphrodite flowers commence opening in every case three or four days earlier than the male flowers. It also seems clear that the semi-compact or loose headed types like *Budh Perio* 10 and *Sholapuri* 1 complete the opening more rapidly than the others, even though the total number of flowers is equally great. In *Althan Deshi* 6, first earhead, the total number is small (669 hermaphrodite flowers as against over 1,000 in all other cases), the flowering still requires nine days to complete.

The progress of flowering from day to day was recorded for some of the above earheads, for both kinds of flowers, and the following table shows the result. The first day of flowering is in all cases the date of opening of a hermaphrodite flower.

TABLE V.

Progress of flowering in Jowar panicles I.

Days of flowering	VARIETY AND STRAIN							
	ALTHAN DESHI 6						BUDH PERIO 40	
	1st earhead		2nd Earhead		3rd Earhead			
	Hermaphrodite *flowers*	Male *flowers*	Herm *flowers*	Male *flowers*	Herm *flowers*	Male *flowers*	Herm *flowers*	Male *flowers*
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1st Day	9 7		0					
2nd „	5 8		1 1					
3rd „	8 8		[illegible] 4					
4th „	31 1	1 9	31 [illegible]			1 5		5 0
5 „ „	13 [illegible]	6 7	15 1			9 2		10 0
6 „ „	15 4	12 [illegible]	14 [illegible]	14 8		8 2		32 6
7 „ „	2 [illegible]	10 [illegible]	2 [illegible]	32 [illegible]		10 1		29 5
8 „ „	7 [illegible]	25 7	[illegible]	2[illegible]	not observed	16 6	not observed	8 2
9 „ „	5 4	28 1	3 [illegible]	16 [illegible]		9 2		6 5
10 „ „		3 1	1 [illegible]	3 6		13 6		3 2
11 „ „		6 9	1	3 6		11 6		5 0
12 „ „		3 9		contd to 15th day		10 8		
13 „ „						6 8		
14 „ „						1 4		
15 „ „						0 6		
16 „ „						0 2		

We have similar records for the hermaphrodite flowers only with three other strains as follows:—

TABLE VI.

Progress of flowering (Hermaphrodite flowers only) in Jowar panicles II.

Days of flowering	Variety and Strain		
	Budh Perio 9	*Chapti 8*	*Sholapuri 1*
	Per cent.	Per cent.	Per cent.
1st day	0·2	0·2	1·5
2nd "	2·7	0·7	9·6
3rd "	6·1	3·2	17·0
4th "	13·3	12·5	23·8
5 " "	9·1	21·1	23·5
6 " "	24·2	25·1	14·7
7 " "	18·6	17·3	7·0
8 " "	10·1	12·9	2·6
9 " "	9·9	3·7	0·2
10 " "	1·7	0·2	..
11 " "	0·3	..	..

It is clear, therefore, that in all cases examined the period of most active opening of the male flowers is three or four days later than that of the complete flowers, and they, likewise, complete their opening three or four days later.

Progressive development of complete flowers in different parts of earhead. In the year 1922-23 it was noted that the first complete flowers to open in all the Surat varieties were those at the top of the earhead, and that flowering progresses downward, stage by stage, the flowers on branches belonging to one whorl being usually in about the same stage of blooming. As a rule, flowers at the top of the inflorescence have shed their pollen and closed when the lower flowers of the head are just beginning to bloom.

If an earhead be divided into three portions—upper, middle, and basal—then the complete flowers in the middle portion start about two or three days later than those in the upper part, and those in the basal section one to two days later than those in the middle. The rapidity, or intensity of flowering is greater in the middle than in

either of the other two sections, as the following figures show, starting in each case from the date of commencement of flowering in that section. At such intense flowering periods the pollen from male flowers of the same earhead is available.

TABLE VII.

Progress of flowering (Complete flowers) in different parts of earhead.

—	Top of earhead	Middle of earhead	Base of earhead
Total number of complete flowers opened .	549	882	569
Percentage of flowers on each day			
1st day	12·6	29·2	10·9
2nd "	9·8	32·3	34·3
3rd "	22·5	19·8	22·5
4th "	11·2	15·7	10·8
5 " "	6·1	1·9	11·3
6 " "	6·2	1·1	10·2
7 " "	1·6	..	..

Progressive development of complete and male flowers as affected by exposure. At this stage the very interesting question arose as to how far the rapidity of opening of flowers was affected by exposure to full light and air. One side of each of two earheads (*Althan Deshi* 6) which were naturally partly shaded and the course of flower opening was watched. The difference in the progress of the flowering in different parts of the earhead is shown below; starting in each case from the commencement of flowering in that section.

TABLE VIII.

Effect of exposure in progress of flowering.

—	I. Complete flowers						II. Male Flowers					
	Top of *earhead*		Middle of *earhead*		Base of *earhead*		Top of *earhed*		Middle of *earhead*		Base of *earhead*	
	E.*	P.†	E.	P.	E.	P.	E.	P.	E.	P.	E.	P.
Percentage of flowers opened on each day—												
1st Day	10·7	15·7	32·3	25·4	9·1	12·5	4·2	4·1	7·3	5·8	1·2	6·6
2nd „	9·0	10·7	33·2	31·2	35·7	33·1	19·3	16·6	10·5	8·8	9·1	9·3
3rd „	24·4	19·1	16·2	24·6	24·3	20·8	17·9	35·8	43·3	23·7	48·1	44·8
4th „	42·4	39·2	14·5	16·6	7·5	13·6	24·2	23·3	31·6	38·9	10·4	3·8
5th „	4·5	9·2	2·2	1·6	11·7	11·1	14·0	20·2	4·4	4·6	20·8	13·6
6th „	7·5	4·3	1·3	0·6	11·7	8·9	0·4	..	2·9	8·2	10·4	16·9
7th „	1·5	1·8	..	..	..	..	..	..	..	..	..	..

* E. Exposed flowers. † P. Partly shaded.

The effect of complete or under exposure of the earhead seems therefore not to affect materially the progress of flowering in a single head so far as the number of days is concerned, but the time of day at which flowers open is a little later in the exposed parts of heads.

Development of the essential sex organs of complete flowers. The essential organs of the complete flowers in *Jowar* are enclosed by two glumes. The outer glume is broad and somewhat loose ; the inner glume is narrower and much more firm. At the time of flower opening, the outer glume widens, and the inner one becomes looser. Then the stigma appears in all the Surat *Jowars* and sometime later one anther, and then again, still later, the other two (though not always simultaneously) protrude. The length of time the stigma appears before the anthers varies with different strains, but in two strains in 1926, they came out fifteen to twenty hours before the anthers All the anthers appear, usually, within fifteen minutes from the coming out of the first anther.

The method of opening just described, which prevails in all the Surat varieties of *Jowar*, is quite different from that which takes place in Egyptian varieties of *Sorghum*, (Kaidi and Brown Yolo) when grown at Surat. In these latter, the anthers first appear, and then the stigma comes out later.

As has already been stated, shaded or protected flowers tend to open earlier in the morning of each day during the flowering period than do those which are fully exposed. The reason for this is not clear, and it does not agree with the general assumption in the case.

When it is cloudy the opening of flowers begins very early in the morning. Thus late in November in 1922, when the day maximum temperature was 80° to 93 F., and the minimum temperature was 68 to 70°F., the opening of flowers began at 4 a.m. and was practically finished by 6-30 a. m. On the chilly nights a few days earlier (minimum temperature 56 °F.) the greater number of flowers opened between 8-30 to 10-30 a.m. The flowers generally begin to close after 10-30 a.m., and there is practically no further opening till next day. In 1926, similar observations were made, but when the atmosphere was on the whole more moist, no opening of flowers was noticed before 7 a. m., and it continued till 10-30 a.m.

During the same season it was also noticed that on the same day the flowers in the upper part of the earhead open earlier in the morning than those in the middle, and these latter earlier than those near the base of the inflorescence. The differences are indicated in the following examples when the time of the beginning of opening is that of the *emergence of anthers* after the widening of the glumes. The strain used for these observations was *Althan Deshi* 6.

Date	Time of opening		
	Top of *earhead*	Middle of *earhead*	Base of *earhead*
I. Complete flowers	a. m.	a. m.	a. m.
Dec. 9, 1926	9-10	9-23	9-23
Dec. 10, 1926	9 0	9-30	9-36
Dec. 11, 1926	..	9-23	9-23
Dec. 12, 1926	..	8 0	10 0
Dec. 13, 1926	.	8-0	9-46
II. Male flowers.			
Dec. 12, 1926	9 24	9-30	10 0
Dec. 13, 1926	9-28	9-57	9-42
Dec. 14, 1926	9 0	9-34	9-38

As the season advances, the opening of flowers tends to commence earlier in the morning.

The pollen of Surat jowars. A study was conducted of the germination of pollen of complete flowers of the *Jowar* strain *Althan Deshi* 6, and also of staminate flowers of both *Althan Deshi* 6 and *Dhorio* from Kathiawar. The germination was tried with (1) pure distilled water, (2) 5 per cent. glucose solution, (3) 10 per cent. glucose solution, and (4) 15 per cent. glucose solution. Both fresh and stale pollen were used for the test.

With fresh pollen from complete flowers, germination in distilled water took place after 40 minutes ; in 5 per cent. glucose solution after 30 minutes ; in 10 per cent. glucose solution after 25 minutes ; and in 15 per cent. glucose solution in the few cases where germination took place at all, in about 15 minutes. In this last case, however, the pollen burst after a few minutes. In any case, the germ tube is completely extruded after five to ten minutes.

With stale pollen from complete flowers the germination is a little delayed. Pollen collected on one morning is capable of germination for at least thirty hours, and cross-pollination was successful, after this time, with *Dhorio* pollen on *Althan Deshi* 6 flowers.

With fresh pollen from staminate flowers, germination was obtained in all the media mentioned above. But the pollen grains were found to germinate better and more rapidly than those from complete flowers in the more dilute solutions. Thus 5 per cent. glucose gave better results than 10 per cent. glucose. To some extent

the contents of the pollen placed in 15 per cent. glucose solution became contorted and they failed to germinate. Successful crosses were made with *Dhorio* pollen from staminate flowers on the stigma of *Althan Deshi* 6.

As the pollen from staminate flower germinates more rapidly and better in the more dilute solutions than that from complete flowers, it is very likely that this pollen may be playing a great part in natural pollination.

The Jowar earhead. The general character of the *Jowar* inflorescence has been already described (page 7). But a few more details regarding the earhead as found at the time of grain ripening may now be given. In any case, the head at flowering usually appears more loose than when ripening.

The earhead branches in the Surat *Jowars* are almost invariably short at the base, and those a little above this and at the middle of the earhead are generally the longest, giving very much an oval appearance to the heads.

The length of the peduncle is characteristic of certain varieties, as well as the shape of the head. In *Sholapuri* and *Nialo* types it is long.

In compact headed types at Surat the rachis is always short; in loose headed types it is always long.

The characteristics of earheads of different types, taken for four years, are shown below :—

TABLE IX.

Characteristics of Surat jowar earheads.

Name of strain	AVERAGE LENGTH OF RACHIS		AVERAGE NO. OF BRANCHES PER UNIT LENGTH OF RACHIS.		AVERAGE NO. OF SEEDS PER BRANCH		AVERAGE WEIGHT OF 1,000 SEEDS IN GRM	
	1923-24 to 1925-26	1925-26 to 1926-27	1923-24 to 1925-26	1925-26 to 1926-27	1923-24 to 1925-26	1925-26 to 1926-27	1923-24 to 1925-26	1925-26 to 1926-27
	cm	cm.	*Compact.*				grm.	grm
Althan Deshi 6	8·09	8·70	91·6	93 2	24·3	27·45	36 95	41 2
Budh Perio 7	9 69	9 75	5·1	106 6	19 5	21 8	36 59	38 35
Moni Timberua 7	8 95	9 05	87·1	92 5	21 0	23 35	38 84	41 [illegible]
		Semi-Compact.						
Budh Perio 53	..	11·35	..	99 05	..	21·30	..	14·5[illegible]
Chapti 8	8 12	8 05	74·6	77·65	22·7	21·35	47·39	47 0
Telia Chapti 24	..	10 45	..	72 3	..	27 55	47·8	40 10
Telia Chapti 26	.	10 85	..	81·7	..	23 05	47·1	39 4[illegible]
		Loose.						
Sholapuri 18	..	15·4	..	59·6	..	25 2	.	39 7[illegible]

The statement that a short rachis is characteristic of compact types is generally true, except with *Chapti* 8, which though only possessing a semi-compact earhead has the shortest rachis length. The character of the head is still more determined by the number of branches per unit length (10 cm.) of the rachis. The greater the number of branches per unit length, the more compact the head. The heaviest seeds, *i.e.*, biggest ones, are generally found in semi-compact types. Minor differences noticed are :—

(1) A peculiar narrowing down of the head just below the tip. This is generally found in blunt compact types, but in some it is very obvious as in *Budh Perio* 7. It is due to shorter length of the branches of the two or three whorls below the last, and relatively longer branches of the last whorl at the tip.

(2) A pitted appearance of the earhead at the tip. This is found in *Althan Deshi* 6, and *Budh Perio* 7, both compact types.

(3) A blunt or tapering tip to the earhead. A tapering earhead is generally found in loose headed types, and to a small extent in semi-compact types. It seems due to longer or fewer branches in the last few whorls near the tip. All *Sholapuri* types have a tapering earhead. The types *Budh Perio* 40 and *Chapti* 8 tend in the same direction. A blunt tip is rather characteristic of compact headed types.

(4) A bulge in the earhead, slightly above the base or in the middle. This is due to a sudden reduction in the distance between whorls in the rachis or to the greatest length of one or two branches of a whorl. The appearance is quite characteristic of *Althan Deshi* 6 and *Budh Perio* 53.

(5) A cylindrical appearance of the earhead. This is seen, for example, in *Budh Perio* 40, and appears due to the uniform length of branches in most of the whorls.

NATURAL CROSS FERTILIZATION IN JOWAR AT SURAT.

All the characteristics of the inflorescence and of the individual flowers in *jowars* would suggest that cross-pollination would be frequent. The chances of such cross-pollination would seem to depend on the following factors :-

1. *The time of extrusion of the anthers and stigma.* It has been shown that in many cases such as *Budh Perio* 7 the stigma may be protruded for twenty hours before the anthers of the same flower give pollen. In one case particularly noted with the strain mentioned, the stigma appeared at 5-30 p.m. on December 14th, 1926 ; at 6-30 a.m. on December 15th the stigma had not been pollinated nor were the anthers dehisced ; at 8-30 a.m. in this day, pollination had occurred and the anthers dehisced. It is necessary, therefore, to revise the conclusion reached in

1907-09 by workers at Surat[1] that cross-fertilization was unlikely in *jowars* at Surat. This was confessedly based on experience with Egyptian *jowars*, and it is now clear that the relative time of appearance of the male and female organs varies much with different varieties and strains of *jowar*.

2. *The extent of extrusion of the anthers.* In a number of flowers on an ear-head, the anthers fail to appear at all, or only are very partially extruded. In these cases the chances of cross-pollination are many. In the strain *Althan Desh* 6 both these conditions occurred.

3. *The pollen available when the stigmas are receptive.* The anthers dehisce in most Surat varieties some time after the stigma is exposed, so that the chance of pollination from another flower is very great. There are, moreover, a very much large number of staminate than of hermaphrodite flowers, and the pollen from such staminate flowers germinates more quickly and in weaker solutions than that from the complete flowers. The male flowers start opening and finish opening a little later than the complete flower.

Though all these considerations make a large proportion of cross-fertilization likely, yet how far it does actually occur can only be determined by a direct experiment. Such an experiment was made in two succeeding years, and the method adopted was to take plants which had bred true to certain characters for at least two generations and expose them in alternate lines to plants in which these characters were different and were equally fixed. The characters chosen for testing the extent of cross-fertilization were as follows : -

1. Colour of midrib of leaf white or greenish.
2. Anther colour, after weathering, yellow, red or brown.
3. Earhead texture compact, semi-compact or loose.
4. Grain colour white, whitish yellow or yellowish.
5. Glume character the extent to which the seeds are covered.

With regard to some of these characters, observations of importance have previously been made. It may be noted that the colour of the midrib is important, as it seems to be correlated with the sweet or pithy character of the stem.[2] Hilson, working in Madras, has observed that a white midrib means a pithy stem when the plant is in shot blade and for some time after. Further he has noted that in breeding tests the pithy character of the stem, and hence the white midrib, behaves as a simple dominant to the sweet stemmed character and hence to the green midrib.

In connection with the question of anther colour, [3] Graham, working at Nagpur, has noted that in his experience the colour of the grain can be judged at the time of flowering, the stamens and stigmas of plants giving red grains being orange in colour

[1] *Annual Report, Bombay Department of Agriculture*, 1907-08, page 17 ; 1908-09, page 20.
[2] *Agri Journ. India*, Vol. XI, p. 154.
[3] *Mem. Dept. Agri., India, (Bot. Ser.)*, VIII, No. 4.

and the colour in the case of types with white or yellowish grain being pale yellow. This observation, it may be noted, does not apply entirely to the *jowar* at Surat, for there exist both yellow and red anthered types with white and yellowish grain.

As regards the question of colour of grain and texture of earheads, observations have been made by Kottur and Kulkarni[1] working at Dharwar and they have used them as a means of testing the amount of cross-fertilization. Judged by the presence of earheads of intermediate texture and brown grain colour, in the progeny of single selected earheads placed at different distances in the field, they have stated that contamination from a variety grown round the border of a field varies from nothing up to 12 per cent. according to the distance from the border.

Other observations on the extent of cross-fertilization have been made by C. R. Ball[2], in America, who states that contamination between adjacent rows may be anything up to 50 per cent. Graham's figure (*loc. cit*) varies from 0·6 to 20 per cent. Naturally, the figure would vary according to the position, the nature of the variety from which contamination takes place, the distance from the source of contamination, and the prevailing environmental conditions.

Now, in the first place it was desired to ascertain with regard to the midrib and anther character above referred to, as to what is the extent to which plants with these characters can be relied on to breed true when the parent earhead has been bagged and so self-fertilization secured, or when an ordinary unbagged earhead is taken from the field.

Midrib character. In 1922-23, it was found that the seed obtained from unbagged earheads on green ribbed plants in selections of *Sholapuri Jowar* bred true, while those from the white-ribbed plants were variable in this respect. In certain cases they bred true ; in others they gave a ratio of white ribbed to green-ribbed plants in the progeny of 5 3 or 5 1 to 1.

In 1924-25, in a selection from *Chapti jowar* in culture made with seed from bagged heads, all the plants from a green-ribbed parent bred true to this character and this is not in one but in several selections. In the case of selection 48 (from a white-ribbed parent) two out of three cultures bred true ; the third gave a ratio of white to green-ribbed plants of 2 to 1.

Anther character. In 1923-24, it was found that the seed obtained from mother earheads with red anthers either gave entirely flowers likewise with red anthers or flowers with red and yellow anthers in various proportions from 2 9 to 5 3 to 1. Where the mother plant had yellow anthers, however, the progeny bred true in this respect. This latter fact was also the case in a series of cultures made in 1924-25, when again red or brown anthered mother plants gave very variable results, red or brown anthers being 1·7 to 4·1 times more numerous than yellow anthers in the progeny.

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[1] *Agri. Journ. India*, Vol. XVII, p. 413.
[2] C. R. Ball. *American Breeder' Assn.*, Vol. VI, p. 103

We have thus a clear method of determining the extent of cross-fertilization by observing these characters. If seeds from strains are taken which have a green midrib and yellow anthers, the progeny will breed true to these characters unless it has been crossed with a strain with white midribs to the leaves or with red or brown anthers.

Such strains were, therefore, selected for the experiment in 1923-24, the ones chosen being *Budh Perio* 9 and *Sholapuri* 1. The characteristics of each are shown in the following Table :—

Character	*Budh Perio* 9	*Sholapuri* 1
Midrib of leaves	green	white.
Anther colour	yellow	red.
Earhead texture	compact	loose.
Grain colour	yellowish	whitish.

The strains used represented the progeny of selfed earheads and were pure as to the characters considered. The flowering time was practically identical. Two rows of *Budh Perio* 9 were planted immediately to the south of several rows of *Sholapuri* 1 and the seed from each row of the former was preserved and sown. The distance between the rows was three feet, so that the first row was three feet and the second row was six feet to the south of the first line of *Sholapuri jowar*.

The result was observed in the crop of 1924-25, taking the progeny of six different plants selected at regular distance from each row and the amount of crossing judged by the number of plants with white midribs to the leaves and red or brown anther colour. The results are shown in the following Table :—

No of plant	No. of plants with characters of mother	No. of plants with white midribs, red anthers, semi-compact earhead	Percentage of crossed plants
I. Row of *Budh Perio* 9, three feet distance from *Sholapuri* 1.			
	53	15	22·0
2	66	22	25·0
3	84	13	13·4
4	64	24	27·3
5	74	15*	16 8
6	52	43	45·3
Total average	39.3	132	25 0

* One of these plants had green midrib, red anthers, and semi-compact head.

No. of plant	No. of plants with characters of mother	No. of plants with white midribs, red anthers, semi-compact earhead	Percentage of crossed plants
II. Row of *Budh Perio* 9, six feet distance from *Sholapuri* 1.			
1	72	7	8·9
2	72	7	8·9
3	60	28	31·3
4	59	29	33·0
5	50	31*	38·3
6	64	26†	29·0
Total average .	377	128	25·0

* Five of these plants had green midribs, red anthers, and semi-compact heads.
† One of these plants had green midrib, red anthers and semi-compact heads.

The naturally crossed plants had their leaves with white midrib and earheads with brown anthers, the head being of a semi-compact character.[1] The anther colour was not truly red and appeared to be intermediate between that of the parents.

The extent of cross-fertilization varies from 13 per cent. to 45 per cent. in the nearer row, and from 9 per cent. to 38 per cent. in the second row from the *Sholapuri* 1 type. Not a single one of the heads used as representatives,—taken fairly equidistant along the rows had been unaffected by the nearness of the contaminating type. It is curious to find that the average amount of crossing is the same in the second as in the first row (though the maximum and minimum are lower in the second row) and it suggests that some other influence than that of the wind is at work,—probably insects.

Such were the results obtained in 1923-24. In the following year, at Surat, a similarly arranged experiment was conducted with the strain *Chapti* 8, again using *Sholapuri* 1 as the means of contamination. The distances of rows of *Chapti* 8 from the contaminating row of *Sholapuri* 1 varied from three feet to thirty-six feet, and the amount of crossing was as follows :—

Distance from row of *Sholapuri* 1.	Percentage of crossing
3 feet	5·2
6 and 9 „	0·5
12 and 15 „	1·5
18 and 21 „	2·1
24 and 27 „	2·6
30 and 33 „	0·5
36 „	2·0

[1] One of the Madras workers has stated the open head character is dominant over the compact head. *Journal of Madras Agricultural Students' Union,* Vol. XII, No. 1 (1924).

It is clear that in 1924-25 the amount of crossing was far less than in the previous year, and that it was not proportionate to distance.

An inspection of a crop raised from unselfed heads of the strains *Althan Deshi* 6 and *Moni Timberwa* 7 in the same year, gave a crossing percentage of 2·2 per cent. and 2·3 per cent. in two cases.

In summary, it would now seem certain that extensive crossing does take place under natural conditions between different strains of *Jowar* at Surat, which may go up to between 40 and 50 per cent. It varies, however, very much from season to season. As the amount does not vary with the distance of the contaminating agent, it seems probable that other agencies than that of the wind are at work, probably insects, and we may, so far as Surat is concerned, decide that the conclusion reached in 1908-09 that natural cross-fertilization does not take place in *Jowar*[1] is not correct.

The hereditary nature of certain characters in Surat jowars.

From the description of the three main varieties of Surat *jowar* (page 3), it will be seen that what goes under the name of a variety, —whether it be *Perio*, *Chapti* or *Sholapuri*, - is really a series of strains, most of which possess certain varietal features, but which differ from one another by important botanical and economical characters. These strains are, however, not merely mixed, but have crossed and recrossed with one another to an enormous extent, and few, if any, of a pure character now exist in the whole district. Any attempt to improve the character of the *jowar* grown, or even to fix standard types, must be commenced by the development of strains breeding true. For this purpose, therefore, original selections from *jowars* of each variety growing in the field were made in 1922-23 and subsequent generations of these selections have been grown from seed obtained from self fertilized covered heads since 1923-24. Crops have always been grown by dibbling seed eighteen inches apart in rows three feet from one another.

Apart from the primary object of the work, namely, to develop fixed strains of special economic value, the selections have been studied in order to find out (1) what characters show constancy and similar differences from strain to strain in a series of years, and which are thus of a hereditary nature and can be fixed by breeding, (2) what is the normal variability of such hereditary and also of other characters from season to season, (3) whether there are any other characters normally associated with a high yield of grain, so that these may be produced in any possible way. During the study, many selections which neither possessed economic value themselves nor which showed characters which would be useful in crossing were abandoned, - but even these have given results of importance to the present study.

[1] *Annual Report, Department of Agriculture, Bombay*, 1908-09, page 21.

The characters which have been studied in the manner described are as follows :—

A. The leaf area per plant.
B. The hairiness and colour of the leaves.
C. The height of the plant.
D. The thickness of the stem.
E. The number of nodes on the stem.
F. The colour of the shrivelled anthers.
G. The number of days from germination to flowering.
H. The length of the rachis.
I. The number of branches on the rachis.
J. The characters of the seed, including size, plumpness, uniformity and colour and the weight of the seeds.

A. The leaf area per plant.

The leaf area per plant may be considered as the area of the leaf blades *plus* the area of the leaf sheaths. In 1923-24, all the leaves of sixty-five plants of selections from the *Perio*, *Chapti*, and *Sholapuri* varieties were measured. It was found that in 66·2 per cent. of cases, the fourth leaf from the top represented approximately the average size of all the leaves of the plants. In 19·7 per cent. of cases, the fifth leaf represented the average, and in 11·1 per cent. of cases, the third leaf was in this position. In succeeding years, the fourth leaf only was measured and was taken as representing the average, and its area multiplied by the number of leaves per plant was taken to represent the leaf area of the plant.

The area of the fourth leaf was determined by treating the blade and the sheath separately as follows :—

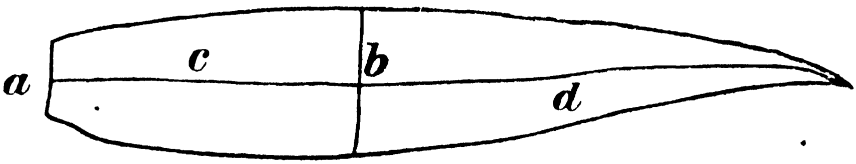


Fig 1

In the blade, four measurements were made, namely—

1. (*a*) The width at the base.
2. (*b*) the width at the maximum breadth.
3. (*c*) the total length of the blade.
4. (*d*) the length from the point of greatest breadth to the tip.

The blade area was then approximately obtained as follows :—

$$\frac{a+b}{2}(c-d)+\tfrac{1}{2}b\times d.$$

The sheath area of the whole plant was considered as a cylinder whose length was the height of the plant up to the flag, and whose diameter was that of the middle internode of the plant at the midpoint.

There are thus three main factors determining the leaf area, namely the total length of leaf, the maximum breadth of leaf, and the number of nodes or leaves. Since 1925-26, the lamina area has been obtained from the fourth leaf by Amsler's Plenimeter.

In studying the results, it will be well to take the lamina or blade area of the fourth leaf first. The criterion used in this as in all other cases for determining how far a character is hereditary is to see how far *relative* differences persist from year to year when conditions of cultivation are similar in different strains. In the present case, the figures for 1926-27 are not quite comparable with the others, as owing to a bad attack of borer and to irregularity caused by heavy excessive rains the planting was not quite regular. The results with four strains are given, however for four years, and for others for two years.

TABLE X.

Blade area of fourth leaf of jowar strains.

Strain	Blade Area in square centimeters				
	1923-24	1924-25	1925-26	1926-27	Average of 1923-26
	sq. cm.	sq. cm.	sq. cm.	sq. cm.	sq. cm.
Atthan Deshi 6	204	216	247	333	222
Budh Perio 7	233	221	285	326	246
Moti Timberva 7	236	251	273	288	254
Chapti 8	244	221	220	277	228
Sholapuri 1	230	250	..	..	..
Budh Perio 40	162	154	..	..	..
Budh Perio 53	..	..	259	387	..
Telia Chapti 24	..	..	245	369	..
Telia Chapti 26	..	..	205	322	..
Sholapuri 18.	..	..	223	322	..

The most that can be said from these figures is that certain strains have large leaves like *Moni Timberwa* 7, and others have small leaves like *Budh Perio* 40. In smaller differences, there seems little if any regularity.

If we now take similarly the whole leaf area of the plants in each year, the following figures are obtained.

Table XI.

Total leaf area per plant in jowar strains.

Strain	Total leaf area in square centimetres				
	1923-24	1924-25	1925-26	1926-27	Average 1923-26
	sq. cm.	sq. cm.	sq. cm.	sq. cm.	sq. cm.
Althan Deshi 6	3,046	4,099	5,127	4,373	4,091
Budh Perio 7	3,609	4,166	5,929	4,099	4,568
Moni Timberwa 7	3,641	4,798	5,823	3,284	4,754
Chapti 8	3,905	4,147	4,270	3,316	4,107
Sholapuri 1	3,122	4,691	..	..	..
Budh Perio 40	2,386	2,931	..	..	..
Budh Perio 53	..	..	5,563	6,002	..
Telia Chapti 24	..	..	4,863	5,416	..
Telia Chapti 26	..	..	4,172	4,677	..
Sholapuri 18	..	..	4,764	4,372	..

From these figures it seems quite evident that the leaf area is only hereditary in the broadest sense. There are certainly strains with low leaf area like *Budh Perio* 40 and others with high leaf area in all the normal years tested, like *Budh Perio* 53 or *Moni Timberwa* 7. But apart from this broad difference, the order of leafiness among the plants varies very much from year to year, and is evidently determined more by the question of whether the environmental conditions of that particular season suits that particular strain or not.

But one association does appear to exist at least among the Surat types examined. The earliness or lateness of flowering seems constantly associated with the amount of leaf area per plant. An early plant has a small leaf area, and *vice versâ*. *Budh Perio* 40 which has the lowest leaf area is the earliest. Next stands *Althan Desh*

6 in both these respects. Similarly, the type with the largest leaf area.—*Moni Timberwa* 7 and *Budh Perio* 53 are the latest. It is not contended that this connection is generally true among types of *jowar*, but it certainly seems to apply among those cultivated in Surat.

Within each strain, the grain yield of each plant has been taken each year, along with the leaf area of each plant, and thus it is possible to determine whether there is any marked correlation between the leaf area and the yield of grain. The results are shown in the following table, where the co-efficient of correlation between these two factors is indicated :—

TABLE XII.

Correlation, within strains, between leaf area and grain yield.

Strain	Co-efficient of correlation of leaf area with yield			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·90 ± 0·02	0·73 ± 0·03	0·85 ± 0·02	0·58 ± 0·01
Budh Perio 7	..	0·81 ± 0·03	0·87 ± 0·01	0·59 ± 0·01
Moni Timberwa 7	..	0·85 ± 0·02	0·86 ± 0·02	0·72 ± 0·01
Chapti 8	..	0·87 ± 0·02	0·92 ± 0·02	0·77 ± 0·03
Budh Perio 53	..	..	0·82 ± 0·02	0·49 ± 0·04
Telia Chapti 21	..	..	0·89 ± 0·02	0·81 ± 0·02
Telia Chapti 26	..	..	0·83 ± 0·02	0·75 ± 0·03
Sholapuri 18	..	..	0·88 ± 0·03	0·72 ± 0·03

It will be seen that, within each strain, there is a very close relationship between the leaf area and the yield of grain, or in other words, any treatment which will increase the leaf area will also increase the yield of grain, whether this treatment be by cultural changes or manurial methods.

B. Hairiness and colour of the leaves.

At the ligules there is always a fringe of hairs, and this always extends on the midrib to about one inch from the base either on one side or on both. In all the varieties there are strains whose general hairiness on the leaf is very different.

Thus if the types isolated be classified according to hairiness, the following is the result :—

Perio types. Out of twenty types isolated, sixteen are hairy, two are sparsely hairy, and two are glabrous or very nearly so.

Chapti types. Out of ten types isolated, three are hairy, three are sparsely hairy, and four are glabrous or very nearly so.

Sholapuri types. Out of seven types isolated, four are hairy, two are sparsely hairy, and one is glabrous or very nearly so.

The *Chapti* types are on the whole the least hairy, while the large majority of the *Perio* and *Sholapuri* strains are hairy. The hairs drop off as soon as the leaves dry up.

The hairy character remains highly constant from generation to generation in each type.

Colour of the midrib. If we consider the colour of the midrib, it appears at once that we are in presence of a character which is constant and hereditary and that a white midrib is dominant over a green midrib. This character should be judged after two to two and half months' growth, and has in our experience always been constantly associated with the sweetness or pithiness of the stem. A white midrib to the leaves is, in fact, always associated with a pithy stem of inferior value as fodder and a green midrib to the leaves with a sweet stem of high fodder value.

Out of seventeen pure *Perio* types which have been isolated eleven (65 per cent.) had green midribs and six (35 per cent.) had white midribs. Both bred true to this character during several generations. Out of eight pure *Chapti* types, all had green midribs, and out of five *Sholapuri* strains isolated in a pure condition, two had green midribs (40 per cent.) and three had white midribs (60 per cent). All bred true to this character.

Colour of leaves. If examined after two to three months' growth, there are distinct differences of tint in the green colour. Thus *Althan Deshi* 1 *and* 6 and also *Budh Perio* 42 all have a very characteristic dark green colour of the foliage which marks them out, and enables them to be easily distinguished. It is constant for several generations.

Wax on the sheath of upper leaves. The waxiness of the sheath of the upper leaves varies considerably, but in certain cases it is very great, as in *Althan Deshi* 6. It is constant from generation to generation.

C. The Height of the plant.

The height of the plant has been in all cases measured from the flag, that is to say, the node on the stem from which the peduncle appears down to the first node in the soil. It varies, however, as would be expected, very markedly from season to season, and is largely affected by the number of nodes formed. Thus the reduced height in an unfavourable season due to a lesser number of nodes is only very slightly made up by increase in the length of the internodes.

Variation in height from year to year in a number of pure types is shown below:—

Table XIII.

Average height of plants in Surat jowars.

Strain	Height of plants in centimeters				
	1923-24	1924-25	1925-26	1926-27	Average of 1923-26
Althan Deshi 6	115	163	158	103	145
Budh Perio 7	145	171	178	104	165
Moti Timbarva 7	126	165	156	81	149
Chapti 8	143	163	134	91	146
Sholapuri 1	127	179	..	..	..
Budh Perio 10	109	163	..	..	..
Budh Perio 53	..	..	151	129	..
Telia Chapti 24	..	..	122	115	..
Telia Chapti 26	..	..	138	122	..
Sholapuri 18	..	..	155	124	..

It cannot be stated that there is any constant relationship between the height of the various types of plant. They were nearly all tallest in 1924-25. The most that can be said is that certain strains are normally tall like *Budh Perio* 7 and others normally short (like *Chapti* 8). In smaller differences there seems little of any regularity.

Within each strain, the grain yield of each plant has been taken each year, along with the height of each plant. The results show a very marked correlation between the height and the yield of grain.

Table XIV.

Correlation, within strains, between height and grain yield.

Strain	Co-efficient of correlation of height with yield			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·83 ± 0·03	0·69 ± 0·04	0·75 ± 0·03	0·54 ± 0·05
Budh Perio 7	..	0·56 ± 0·05	0·85 ± 0·02	0·76 ± 0·03
Moti Timbarva 7	..	0·67 ± 0·04	0·86 ± 0·02	0·73 ± 0·04
Chapti 8	..	0·76 ± 0·03	0·90 ± 0·02	0·64 ± 0·05
Budh Perio 53	..	..	0·82 ± 0·02	0·52 ± 0·05
Telia Chapti 24	..	..	0·86 ± 0·02	0·67 ± 0·04
Telia Chapti 26	..	..	0·83 ± 0·02	0·59 ± 0·04
Sholapuri 18	..	..	0·89 ± 0·02	0·48 ± 0·05

The correlation is highest in a dry year as 1925-26, while the lowest is in 1926-27, when the percentage of stand of plants was very poor. Thus, even in a dry year, a tall plant in a field is likely to yield more grain.

D. The thickness of the stem.

The thickness of the stem was taken by measuring the circumference by means of a graduated strip of paper, at the middle of an internode. The internode taken has been always the middle one. Thus, if there are eleven nodes, it will be the sixth, if there are ten or twelve, two measurements are taken one on each of the two middle nodes.

The results are tabulated below :-

TABLE XV.

Circumference of stem of Surat jowars.

Strain	CIRCUMFERENCE IN MILLIMETERS				
	1923-24	1924-25	1925-26	1926-27	Average of 1923-26
	mm.	mm.	mm.	mm.	mm.
Althan Deshi 6	32·5	38·1	42·4	50·9	37·7
Budh Perio 7	38·8	38·9	44·9	50·3	40·9
Moni Timberwa 7	36·2	41·1	44·3	46·0	40 5
Chapti 8	38·2	38·3	37·4	43·0	38 0
Sholapuri 1	35·0	39·4	39·7	..	38 0
Budh Perio 40	30·5	32·5	..	..	.
Budh Perio 53	..	..	44·0	60·	..
Telia Chapti 24	..	..	41·4	54·8	..
Telia Chapti 26	..	..	39·1	51·5	..
Sholapuri 18	..	..	43·2	49·7	..

There is at least a suggestion in these figures that among the Surat *jowars* a thin stemmed type is likely to be an early one, and a thick stemmed type a late

one. Thus *Budh Perio* 40 has the thinnest stem, and is earliest in flowering. *Budh Perio* 53 is the thickest stemmed strain, and is the latest in flowering.

Within each strain the plants with the thickest stem have generally given the highest yield, and the correlation between thickness of stem and the yield has proved to be high. The following Table shows the co-efficient of correlation of these factors in three successive years :—

TABLE XVI.

Correlation, within strains, between stem thickness and grain yield.

Strain	Co-efficient of correlation of stem thickness with yield		
	1924-25	1925-26	1926-27
Althan Dudhi 6	0·80 ± 0·03	0·92 ± 0·01	0·65 ± 0·01
Budh Perio 7	0·78 ± 0·03	0·91 ± 0·01	0·52 ± 0·05
Moni Timbarwa 7	0·91 ± 0·01	0·93 ± 0·01	0·72 ± 0·01
Chapti 8	0·88 ± 0·01	0·98 ± 0·01	0·73 ± 0·01
Budh Perio 53	..	0·93 ± 0·01	0·52 ± 0·05
Telia Chapti 24	..	0·85 ± 0·02	0·76 ± 0·02
Telia Chapti 26	..	0·88 ± 0·01	0·54 ± 0·04
Sholapuri 18	..	0·92 ± 0·02	0·80 ± 0·02
Sholapuri 1	0·87 ± 0·02	..	..

E. The number of nodes in the stem.

The number of nodes in the stem varies from year to year, but there is little relationship between the number of internodes and the height of the plants. Though in 1926-27 the number of nodes was the least in our series of years, and the height of the plants was likewise the least, yet in 1925-26 when the number of nodes was the greatest in the series, the height was not the greatest owing to adverse conditions of drought in the latter part of the season.

The following Tables show the number of nodes in a series of years in strains of Surat *jowars*, and the average length of internode in each strain :—

TABLE XVII.

The number of nodes in stems of Surat jowars.

Strain	Average number of nodes			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	13	16	18	13
Budh Perio 7	13	16	18	11
Moni Timberwa 7	13·5	16·5	18	10
Chapti 8	14	16	16·5	10·5
Budh Perio 53	..	..	18·5	13·5
Telia Chapti 24	..	..	17·5	13
Telia Chapti 26	..	..	18	12·5
Budh Perio 40	12·5	15·5	..	..
Sholapuri 1	13·0	16	..	..
Sholapuri 18	..	..	18	11·5

TABLE XVIII.

Length of internodes in stems of Surat jowars.

Strain	Average length of internode			
	1923-24	1924-25	1925-26	1926-27
	cm.	cm.	cm.	cm.
Althan Deshi 6	9·6	10·8	9·3	8·6
Budh Perio 7	12·1	11·5	10·6	10·4
Moni Timberwa 7	10·1	10·7	10·6	9·0
Chapti 8	11·2	10·9	8·6	9·3
Budh Perio 53	..	..	8·7	10 4
Telia Chapti 24	..	..	7·4	9·7
Talia Chapti 26	..	..	8·2	10·5
Budh Perio 40	9·4	11·2	..	..
Sholapuri 1	10·6	11·9	..	..
Sholapuri 18	..	..	8·5	11·7

The average length of internodes seems to be little, if any, guide to the character of a strain, and seems pre-eminently to be the character of the season in which the *jowar* is being grown. The length of the internodes, even in a particular part of the season, seems to reflect the vigorous or poor growth at that part of the season.

Thus in 1925-26, a year of drought in the latter part of the season, the upper internodes were very short. But with all this, there are characteristic differences of the strains in extreme cases only, which persist throughout. Thus the *upper* internodes were always shorter in the case of *Althan Deshi* 6 than in any other of the strains in hand, while in *Sholapuri* 18 they were always the longest.

Within a strain, the number of nodes seems to have some relationship to the yield of grain, though the correlation is not very constant or very close. In 1926-27, when as has already been stated the conditions of growth were abnormal, it almost disappears. In other cases, a large number of nodes seems to indicate a vigorous and hence a high yielding plant.

TABLE XIX.

Correlation, within strains, between number of nodes in the stem and grain yield.

Strain	Coefficient of correlation of number of nodes with yield			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·74 ± 0·04	0·79 ± 0·03	0·74 ± 0·04	0·24 ± 0·06
Budh Perio 7	..	0·68 ± 0·04	0·87 ± 0·02	0·23 ± 0·06
Moni Timberwa 7	..	0·83 ± 0·02	0·86 ± 0·02	0·35 ± 0·07
Chapti 8	..	0·82 ± 0·02	0·87 ± 0·02	0·24 ± 0·08
Budh Perio 53	..	..	0·81 ± 0·03	0·20 ± 0·06
Telia Chapti 24	..	..	0·66 ± 0·04	0·30 ± 0·06
Telia Chapti 26	..	..	0·73 ± 0·03	0·27 ± 0·06

F. The colour of the shrivelled anthers.

The colour of the shrivelled anthers seems an absolutely constant character from generation to generation and hence has great value in roguing out forms which are not true to type.

The anther character has been discussed in detail in connection with the study of the natural cross fertilization of *jowar*, and it was found that a yellow colour in these organs was completely recessive, the red or brown colour being dominant.

Each of the current varieties is mixed in the matter of anther colour, for strains with yellow anthers can be found among *Perio*, *Chapti* and *Sholapuri* types, strains with brown anthers have been detected among both *Perio* and *Sholapuri* types, while strains with red anthers are found in all the three series of types.

G. The period from germination to flowering.

The length of the time between germination and flowering is, on the whole, a very constant character, that is to say, the relationship as to earliness between different strains is maintained in seasons of very different characters, and within the strain the plants differ very little in this feature. It must be made clear, however, that an early flowering type is not *necessarily* an early ripening type. Our study indicates that though a type may be late in flowering yet it may ripen almost at the same time as one which flowered much earlier. This is important, because the need is felt for types which can be sown late, and yet can be relied upon to mature the grain fully, and the introduction of varieties like *Sholapuri* and *Khaplatio-Nialo* is largely due to their advantage in this respect.

The average flowering period has been worked out, in connection with the figures which follow, by counting the number of days from the general date of germination to the flowering of a number of individuals, and then taking the average of the figures so obtained. The actual figures for ten strains of *jowar* and for the local mixed *Perio* variety at Surat are shown in the following Table. The figures for 1926-27 are not entirely comparable as the stand of plants in that year was very irregular owing to excessive rain and to borer attack.

TABLE XX.

Period from germination to flowering in Surat jowars.

Strain	Average number of days from germination to flowering				
	1923-24	1924-25	1925-26	1926-27	Average 1923-26
Althan Deshi 6	114	100	101·5	125	105·3
Budh Perio 7	115	104·5	107·5	141·5	109
Moni Timberwa 7	118	105·5	111	144	111·3
Chapti 8	116	104·5	111	145·5	110·5
Sholapuri 1	121	105	107	..	111
Budh Perio 40	112	92·5	98	..	100·8
Budh Perio 53	..	..	119	137·5	..
Telia Chapti 24	..	..	120	115	..
Telia Chapti 26	..	..	120·5	145·5	..
Sholapuri 18	..	..	116·5	145·5	..
Local *Perio Jowar* at Surat Farm	123	..	119	136	..

These figures clearly indicate that the order is very closely maintained in the first three years, which alone are comparable, for the reasons already given, and that thus the character is definitely a hereditary one. *Sholapuri* types, when grown under identical conditions, are not earlier than the *Perio* types. They will, however, flower normally if planted late which many of the *Perio* types fail to do.

The plants within a strain show that there is a distinct *negative* correlation of earliness with high yield though the extent of the correlation varies much from year to year and in 1926-27 disappears in some cases, possibly owing to the irregular and unusual conditions of cultivation in that year.

TABLE XXI.

Correlation, within strains, between early flowering and grain yield.

Strain	Co-efficient of correlation of early flowering with yield			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·64±0·06	0·59±0·05	0·60±0·04	0·28±0·06
Budh Perio 7	..	0·40±0·07	0·22±0·06	0·18±0·06
Moni Timbarwa 7	..	0·52±0·05	0·33±0·06	0·32±0·08
Chapti 8	..	0·71±0·03	0·60±0·01	0·45±0·05
Sholapuri 1	..	0·25±0·07	..	..
Budh Perio 53	..	..	..	0·36±0·06
Telia Chapti 24	..	..	0·31±0·01	0·41±0·05
Telia Chapti 26	..	..	0·31±0·06	0·59±0·05
Sholapuri 18	..	..	0·18±0·01	0·24±0·06

II. *The length of the rachis.*

The earhead characters as a whole are, as would be expected, very much more constant than the vegetative ones. The length of the rachis, which determines very largely the general appearance of the earheads, varies, in fact, very little from season to season and would be expected to be definitely hereditary. It has been measured from the scar of the lowest branch to the tip from which a large number of

branches arise. The actual results of such measurements are shown in the following Table :—

TABLE XXII.

Length of rachis in Surat jowars.

Strain	Average length of rachis in centimeters			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	7·9	8·1	8·3	9·1
Budh Perio 7	..	9·2	10·2	9·5
Moni Timberwa 7	8·8	8·9	9·2	8·9
Chapti 8	..	7·7	7·7	8·4
Sholapuri 1	11·2	13·6	..	..
Budh Perio 53	..	..	11·2	11·5
Telia Chapti 24	..	..	10·3	10·6
Telia Chapti 26	..	..	11·2	10·5
Sholapuri 18	..	..	15·7	15·1
Local *Perio Jowar* at Surat Farm	9·0	..	9·3	10·3

The relation between the different strains is almost similar throughout. In 1926-27 there is an exception in the case of *Althan Deshi* 6 and *Moni Timberwa* 7, but the differences in spacing that year deprive this result of much value. The general agreement, however, makes it certain that we are in face of a genuine hereditary character only modified to a limited extent by environmental conditions.

Within the strain, the longer rachis gives the higher yield, and there is, as would be expected, usually a high correlation between these two. Selection for high yield by picking the longer heads is justified by the following figures :—

TABLE XXIII.

Correlation, within strains, between length of rachis and grain yield.

Strain	Co-efficient of correlation of rachis length with yield			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·85 ± 0·03	0·57 ± 0·05	0·38 ± 0·06	0·21 ± 0·09
Budh Perio 7	..	0·55 ± 0·05	0·59 ± 0·04	0·41 ± 0·05
Moni Timberwa 7	..	0·74 ± 0·03	0·71 ± 0·04	0·58 ± 0·06
Chapti 8	..	0·57 ± 0·05	0·50 ± 0·08	0·47 ± 0·06
Sholapuri 1	..	0·30 ± 0·07	..	..
Budh Perio 53	..	..	0·69 ± 0·04	0·53 ± 0·05
Telia Chapti 24	..	..	0·61 ± 0·03	0·91 ± 0·01
Telia Chapti 26	..	..	0·81 ± 0·02	0·72 ± 0·03
Sholapuri 18	..	..	0·58 ± 0·07	0·42 ± 0·05

I. The density of branches on the rachis.

The number of branches on the rachis is determined in any case by counting the number of branches from base to the tip. There is liable to be a little confusion near the tip, but in the measurement adopted, a branch having two branchlets of spikelets is nevertheless considered as one branch. The most useful figure, however, is not the total number of branches but the number per unit length (say per 10 centimeters) or, in other words, the density of branches on the earhead. The actual figures in this connection in a series of strains are as follows :—

TABLE XXIV.

Density of branches in earhead.

Strain	Average number of branches per 10 centimeters of rachis length				
	1923-24	1924-25	1925-26	1926-27	Average 1923-27
Althan Deshi 6	92·6	88·7	93·6	92·9	91·6
Budh Perio 7	..	87·8	102·1	111·2	..
Moni Timberwa 7	88·3	83·0	90·0	95·0	87·1
Chapti 8	..	70·6	75·9	80·2	..
Sholapuri 1	47·1	47·0	..	..	..
Budh Perio 53	..	..	85·2	112·9	..
Telia Chapti 24	..	..	64·8	79·8	..
Telia Chapti 26	..	..	67·4	96·0	..
Sholapuri 18	..	..	45·1	56·1	..
Local Surat *Perio*	81·4	..	82·8	98·9	..

The relative density of branches per earhead is very closely similar in the different strains in all years except 1926-27, when the condition of growth unfortunately was not very uniform in the different strains. The wider differences are quite clear, the looseness of the *Sholapuri* types, and the looseness of the *Chapti* and *Telia Chapti* strains as compared with the *Perio* types.

Within the strains, the correlation of the number of branches with yield is very close, the co-efficient of correlation being $0·83 \pm 0·03$ with *Althan Deshi* 6 in 1923-24, was about 0·80 in all the strains except *Sholapuri* 1 in 1924-25. It was over 0·60 in all cases in 1925-26, but was much lower in 1926-27, varying from $0·37 \pm 0·05$ with *Sholapuri* 18 to $0·61 \pm 0·05$ with *Moni Timberwa* 7. Within a strain, therefore, a

dense earhead, that is to say, a large number of branches in an earhead, means a high yield.

The number of seeds per branch of the rachis varies much from season to season, especially with some types. Records are only available in a few cases, but these have given the following figures :—

TABLE XXV.

Number of seeds per branch of rachis.

Strain	Average number of seeds per rachis branch			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	22·6	23·8	26·5	28·4
Budh Perio 7	..	18·1	19·7	23·9
Moti Timbarwa 7	19·4	22·6	21·1	25·6
Chapti 8	..	25·5	20·0	22·7
Sholapuri 1	21·8	26·5	..	..
Budh Perio 53	..	..	19·0	23·6
Telia Chapti 24	..	..	23·7	31·4
Telia Chapti 26	..	..	16·8	29·3
Sholapuri 18	..	..	21·9	28·5

It will be seen that the high number of seeds per branch is maintained in *Althan Deshi* 6, and the number in *Budh Perio* 7 remains low throughout, others are very variable indeed.

J. The character of the seed.

(*a*) *Seed weight.* It may be noted, first, that the seed weight varies on the same earhead, the seed at the top being generally the heaviest, the middle ones coming next, and that at the base being the lightest. This is illustrated by the following figures, being the weight of 1,000 grains in 1925-26, from various parts of the earhead in a number of strains.

Top of earhead (16 per cent. of total) 18·9 grams per 1,000 grains.
Middle of earhead (57 per cent. of total) 17·7 grams per 1,000 grains.
Base of earhead (27 per cent. of total)—45·3 grams per 1,000 grains.

Average. 46·6 grams per 1,000 grains.

Taking the average weight of the seeds from the whole heads by counting 23 grams of seed, the following figures have been obtained :--

TABLE XXVI.

Weight of seeds in Surat jowars.

Strain	WEIGHT OF 1,000 SEEDS IN GRAMS				
	1923-24	1924-25	1925-26	1926-27	Average 1923-26
	grm.	grm.	grm.	grm.	grm.
Althan Deshi 6	37·1	43·6	30·1	52·3	36·9
Budh Perio 7	..	42·7	30·7	46·0	..
Moti Tamberwa 7	37·3	45·3	33·9	49·2	38·8
Chapti 8	48·9	53·9	39·3	51·7	47·3
Sholapuri 1	33·6	39·5	..	..	..
Budh Perio 53	..	47·0	31·3	57·8	..
Telia Chapti 24	..	48·1	27·2	53·6	..
Telia Chapti 26		47·0	32·3	46·6	..
Sholapuri 18	..	46·6	32·1	47·4	..

Beyond the fact that the *Sholapuri* types are light seeded and the *Chapti* types are heavy headed, there seems little regularity in these figures. The actual relative size of seed seems to be far more under the influence of the environment of the particular season than to be determined by hereditary influences. Except in the broadest sense, there seems little reason for supposing that because a type gives a large seed one year, it will give a large seed in another year under different environmental conditions.

(*b*) *Seed size and uniformity.* This has been measured in two ways, namely, (1) sieving not less than five pounds of the seed through sieves having round holes 3 millimeters, 4 millimeters, and 5 millimeters in diameter. The seed sieved is then weighed and the average grade of the sample calculated from the percentage of grain under different heads. (2) by the use of the 'grain tester' which enables the weight per bushel to be determined on a small sample.

The results by each of these methods in the same lot of seeds, of four strains, in 1925-26 were as follows. The average grade of seed means the diameter of the circular holes in the sieve through which the average seed would just pass. The

grain tester reading means the volume in cubic centimeters of 150 grams of grain filled by pouring gently into the measuring vessel.

These are compared with the weight in grams of 1,000 seeds :—

Strain	Grain values in 1925-26		
	Average grade of seed	Grain Tester reading	Weight of 1,000 seeds
	mm.	c.c.	grams
Althan Deshi 6.	4·07	127·2	30·1
Budh Perio 7	4·15	129·5	30·7
Budh Perio 53	4·30	127·3	31·3
Sholapuri 18	4·23	129·8	32·1

The methods do not agree with one another, and indicate that the grain tester is determining something which is not entirely dependent on grain size or grain weight but also on the capacity to pack closely.

So far as the average grade is concerned, the order of size in the seed for which we have records for three years or more is very nearly the same in each year, as the following Table shows :—

TABLE XXVI.

Average size of grains in Surat jowars.

Strain	Average grade of seed			
	1923-24	1924-25	1925-26	1926-27
	mm.	mm.	mm.	mm.
Althan Deshi 6	4·38	4·43	4·07	4·72
Budh Perio 7	..	4·45	4·15	4·53
Moni Timberwa 7	4·47	4·49	4·37	4·62
Chapti 8	4·62	4·52	4·49	4·99

The only change in order is in 1926-27 when, as already explained, there was some irregularity in planting. The size of the seed is, in fact, a hereditary quality, modified considerably by the conditions of any particular season.

The grain tester results, which represent the volume per unit weight, are also characteristic of the strain in the same sense, as the following figures show :—

Table XXVII.

Grain tester readings in Surat jowars.

Strain	Grain tests readings			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	124·4	121·5	127·2	121·3
Budh Perio 7	127·1	124·2	129·5	126·7
Moni Timberwa 7	128·1	124·1	129·0	127·3
Chapti 8	130·8	127·2	134·8	128·7

It will be noticed that the highest figures with all strains are obtained in the dry season of 1925-26, and in this year, it may be noted, that the grains were the least plump.

(*c*) *Seed characters.* Most of the seed characters such as colour, texture and shape appear to be fully constant and reappear from year to year in pure line cultures. The variation of strains selected from any variety are shown below, where the characteristics of selections breeding true are given.

Table XXVIII.

Characteristics of seeds of Surat jowars.

Strains	Colour of seed	Texture of grain	Shape of grain
I. *Perio* types.			
Althan Deshi 6	Yellowish	Hard	Round.
Budh Perio 7	Do.	Do.	Do.
Moni Timberwa 7	Pale yellowish	Slightly less hard than above.	Flat with gloss and lustre.
Budh Perio 10	Pale yellowish with reddish tips.	Hard	Round.
Budh Perio 53	Whitish	Do.	Round and plump.
Budh Perio 26	Pale yellowish	Do.	Round.
II. *Chapti* types			
Chapti 8	White	Soft	Big and flat.
Telia Chapti 24	Pearly white	Hard	Very flat and big
Telia Chapti 26	Do.	Do.	Flat and big.
III. *Sholapuri* types.			
Sholapuri 1	Dull white	Do.	Round and plump with wavy constructions on surface.
Sholapuri 18.	Pale yellowish	Do.	Round and plump.

Variability among strains of Surat jowars. The variability of the plants grown from selfed seed in any year is a measure of purity, for the variability of a pure type should remain similar from year to year. And, further, a study of the variability enables those characters to be determined, which are least variable, or, in other words, which are most characteristic of the type.

Among the characters studied the least variable in all the strains are (1) the period from germination to flowering, (2) the length of the rachis. The purely vegetative characters (like plant height etc.) are very variable, far more so than the earhead characters like the length of the rachis or the number of branches in the earheads. Some types like *Moni Timberwa* 7 or *Chapti* 8 seem more variable than others like *Budh Perio* 7, though the variability remains similar from year to year.

The variability is best expressed by the co-efficient of variation within the strain, and the following table shows the average for three years for four strains. The cases where only two years' records are in hand are not given but they are of a similar order to those shown :-

TABLE XXIX.

Variability of characters in strains of Surat jowars.

Characters	Co-efficient of variation			
	Althan Deshi 6	*Budh Perio* 7	*Moni Timberwa* 7	*Chapti* 8
1. Plant height	14·1 ± 0·7	10·5 ± 0·5	15·9 ± 0·9	14·2 ± 0·9
2. Leaf area per plant . . .	21·1 ± 1·1	21·1 ± 1·1	26·4 ± 1·5	22·8 ± 1·4
3. Stem thickness	13·6 ± 0·7	12·7 ± 0·6	15·8 ± 0·3	15·2 ± 0·9
4. Number of internodes	9·7 ± 0·4	9·5 ± 0·4	11·5 ± 0·6	9·8 ± 0·7
5. Days from germination to flowering .	3·2 ± 0·2	2·5 ± 0·1	3·0 ± 0·2	2·8 ± 0·2
6. Length of rachis	7·5 ± 0·4	9·0 ± 0·4	9·7 ± 0·5	11·2 ± 0·7
7. Number of branches on rachis . .	10·7 ± 0·5	14·0 ± 0·7	16·1 ± 0·9	16·8 ± 1·0
8. Seed weight	14·9 ± 0·7	10·8 ± 0·5	11·6 ± 0·6	10·4 ± 0·8

Yielding capacity among strains of Surat jowars. In judging the yielding capacity of a strain, and all selections made in connection with the work under record, three methods have been used.

The first of these is in single rows, three feet apart, each composed of about sixty-five plants, sown, by dibbling, direct with the produce of self-fertilized heads, the dibbles being placed at intervals of eighteen inches. The percentage

stand of plants finally obtained is noted, the actual yield is recorded, and the theoretical yield for the full number of dibbles is calculated.

The second is to obtain the yield from replications of four lines each in comparison with the local *jowar*. The yield figures are used as actually obtained as the difference in stand of plants is negligible.

The third is to record the yield in portions of the large area devoted to seed multiplication on the Surat Experimental Station.

Taking all these into account, the yields obtained for a series of strains for two or three years are given below. The yield figures for 1926-27 have not been taken into account in working out averages as the stand of plants that year was not even for reasons already described.

The yield of a number of the strains in 1924-25 and 1925-26 was calculated by the first method only and these cases have been noted :—

TABLE XXX.

Yield per acre of strains of Surat jowars.

Strain	Yield per acre of grain				
	1923-24	1924-25	1925-26	1926-27	Average 1923-27
	lb.	lb.	lb.	lb.	lb.
I. *Perio* types.					
1. *Althan Deshi* 6	1,073	943	930		983
2. *Budh Perio* 7	1,075	976	909	..	987
3. *Moni Timberwa* 7	979	1,091	688	..	919
4. *Budh Perio* 53	..	1,224*	928	1,131	..
6. *Budh Perio* 26	..	1,144*	762	..	..
7. Local *Perio Jowar* Surat	719	914	556	960	730
II. *Chapti* types.					
1. *Chapti* 8	1,096	1,061	660	..	939
2. *Telia Chapti* 24	..	1,403*	741	1,151	..
3. *Telia Chapti* 26	..	1,374*	673	1,296	..
4. Local *Chapti Jowar* Surat	846	1,038	520	903	801
III. *Sholapuri* types.					
1. *Sholapuri* 1	..	1,001	840*	..	..
2. *Sholapuri* 18	..	1,302*	734	1,276	..
3. Local *Sholapuri Jowar* Surat	..	814	573	990	..

* Yield from the first method (in single rows) only.

As regards these results, it will probably be only safe to draw conclusions from those cases where proper records from three years are available. Taking the average of the three years, we have among the *Perio* types, *Althan Deshi* 6 giving 34·6 per cent. higher yield than the local *Jowar* under exactly similar conditions, with a very small variation from the mean; *Budh Perio* 7 is slightly better, on the average, than the last giving an increased yield of 35·2 per cent. more than the local *Jowar*. The variation from year to year is, however, somewhat greater than in the last case. *Moni Timberwa* 7 does exceedingly well in the very favourable season, for growth, 1924-25, but fails badly in the dry season of 1925-26. On the whole, it gives 25·9 per cent. increase on the local *Jowar*. *Budh Perio* 53 is of still greater promise, but the results are not sufficient for final conclusion.

Among the *Chapti* types it is only in *Chapti* 8 that we have material to judge the value of the selection made. Here we have, on three years' average, an increased yield of 17·2 per cent. The *Telia Chapti* selections promise to be still better. No final conclusion can be specified regarding the *Sholapuri* types, but one at least promises well, and will probably give over 20 per cent. increase of yield.

In general, it seems as if, by simple selections, an increase in yield of grain of twenty per cent. or thereabouts can usually be obtained in a crop as highly mixed as the Surat varieties of *Jowar* besides the extra value which is given for the more even grain obtained from a single pure strain of the crop.

Description of certain pure bred strains of Surat Jowar

The characters which differentiate the *Kharif Jowars* of the Surat District from one another have been already described. But the discussion which has followed has shown that all the recognised varieties of the crop are mixtures of strains, which differ from one another by characters of direct or indirect economic importance, and which breed true. These strains are, however, not merely mixed. They have crossed with one another to a very great extent, and few, if any, of a pure character now exist in cultivation. Any attempt to make a permanent improvement in yielding capacity, or even to fix a type which shall approach near to the ideal for this District, must be commenced by the isolation of such pure strains breeding true, which can be used as the basis for establishing types or of making crosses with other varieties.

It is now proposed to describe ten such pure strains, five belonging to the *Perio*, three to the *Chapti* and two to the *Sholapuri* variety, in order to indicate the range of variation in the variety and also the fluctuation within the strain itself. They are only a few examples from a large number of strains isolated, and they are simply described as examples, for the purposes above indicated. The figures of growth etc. are comparable between the strains and are obtained at Surat.

The five strains *Althan Deshi* 6, *Budh Perio* 7, *Moni Timberwa* 7, *Chapti* 8 and *Sholapuri* 1 were isolated in 1922-23 from types growing on the Government

Farm, Surat, and have been grown from self-pollinated seeds ever since. Selection 10 was selected in 1922-23, and has been grown from self-pollinated heads since 1923-24. The remaining strains have been isolated from a number of samples collected in 1922-23 in the Bardoli and Chorashi talukas of the Surat district, and the adjoining areas of the Baroda State, and grown ever since from self-pollinated seeds.

(1) Budh Perio 7.

Habit of growth and vegetative characters. This type is tall, grows vigorously and continuously. The internodes are long. The leaves are longer and narrower than those of *Althan Deshi* 6 and *Moni Timberwa* 7. They are hairy at the tips and the midrib is greenish. The stem is thicker than that of *Althan Deshi* 6. The leaf area is relatively high.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1923-24	145	13	38·8	3,609
1924 25	171	16	38 9	4,166
1925-26	178	18	14·9	5,929
1926 27	104	11	50·3	4,099

Flowering habit and character of inflorescence. The average number of days from germination to flowering was: -1923-24—115 days; 1924-25 105 days; 1925-26 -107 days; 1926-27 141 days. The last is not comparable with the others. The shrivelled anthers are brown, the stigma appeared 20 hours before the bursting of the anthers in 1926-27. The peduncle is long and curved.

Earhead character. The heads are compact, bulging in the middle, and are blunt, with a characteristic narrow depression below the tip due to shorter lenth of two or three whorls below the last, and the relatively long branches at the tip. The length of rachis is long for such a compact type, and has been as follows:— 1924-25- 9·2 cm., 1925-26 - 10·2 cm., 1926-27 9·5 cm. The number of rachis branches is high, being second only (per unit length of earhead to *Budh Perio* 53. The number per 10 cm. length of rachis has been as follows: - 1924-25 -88; 1925-26—102; 1926-27 -111. The number of seeds per branch is small, less than any other *Perio* type, as follows: —1924-25 -18·9, 1925-26 19·7: 1926-27—23·9.

Seed character. The grains are yellowish, hard, and round but are light in weight, 1,000 grains weighed 42·7 grams in 1924-25; 30·7 grams in 1925-26; and 16 grams in 1926-27. As is usual with compact types, the seeds are not very uniform. The

average grade has been in 1924-25—4·45 mm.; in 1925-26—4·15 mm.; and in 1926-27—4·53 mm.

(2) Althan Deshi 6.

Habit of growth and vegetative characters. This type is rather medium in height, particularly the top five internodes which are very short. The stem is also relatively thin. The leaves are shorter and broader than those of *Budh Perio* 7 and have rather less leaf area per plant. They are hairy at the tips and the midrib is greenish. The waxy coating on the sheaths is well developed. The colour of leaves is dark green.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1923-24	115	13	32·5	3,046
1924-25	163	16	38·1	4,099
1925-26	158	18	42·4	5,127
1926-27	103	13	50·9	4,373

Flowering habit and character of inflorescence. The average number of days from germination to flowering was :—1923-24—114 days; 1924-25—100 days; 1925-26—101 days; 1926-27—125 days. The shrivelled anthers are yellow. The number of pedicelled flowers with anthers is the highest.

Earhead characters. The heads are very compact, of moderate size and less blunt than in *Budh Perio* 7. The peduncle is curved and short. The length of rachis is the shortest in *Perio* strains, being only slightly longer than that of *Chapti* 8. It has been as follows :—1923-24—7·9 cm.; 1924-25—8·1 cm.; 1925-26—8·3 cm.; 1926-27—9·1 cm. The number of rachis branches is moderate, the number per 10 cm. length of rachis has been as follows : —1923-24—93 ; 1924-25—89 ; 1925-26—94 ; 1926-27—93. The number of seeds per branch is highest, particularly in relation with the short length of the branches. It has been as follows :—1923-24—22·6 ; 1924-25—23·8 ; 1925-26—26·5 ; 1926-27—28·4.

Seed characters. The grains are yellowish, hard, plump and round. The seed weight is similar to that of *Budh Perio* 7 and 1,000 grains weighed 37·1 grams in 1923-24 ; 43·6 grams in 1924-25 ; 30·1 grams in 1925-26 ; and 52·3 grams in 1926-27. As is usual with the compact types, the seeds are not very uniform. The average grade has been in 1923-24—4·38 mm.; in 1924-25—4·43 mm.; in 1925-26—4·07 mm.; and in 1926-27—4·72 mm.

(3) Budh Perio 40.

This was selected from farm *jowar* for earliness and most of the characters reveal it to be rather nearer to the type of *Nialo jowar* than to the *Perio* variety. It has been studied only for the first two years.

Habit of growth and vegetative characters. This type is short and thin and produces few nodes. The leaves are long and very narrow and have the smallest leaf area of all the Surat *jowars* isolated. The leaves are almost glabrous and have greenish midrib.

Year	Average total height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm
1923-24	109	13	30·5	2,386
1924-25	163	16	32·5	2,931

Flowering habit and character of inflorescence. The average number of days from germination to flowering is the lowest and has been in 1923-24 – 112 days and 1924-25 – 93 days. The shrivelled anthers are red. The number of pedicelled flowers with anthers was very small.

Earhead characters. The heads are semi-compact, of moderate size and almost cylindrical in shape with long straight peduncle. This has not been studied in details as it is a low yielder.

Seed characters. The grains are whitish yellowish with reddish tips, hard, and round but small.

(4) Moni Timberwa 7.

This type was originally selected from a local sample of the famous locality *Moni Timberwa* renowned for the best quality of grain.

Habit of growth and vegetative characters. This type is intermediate in height between *Budh Perio* 7 and *Althan Deshi* 6 with thick stems. The leaves are longer and broader and thus have the largest leaf area per plant. The leaves are hairy at the tips, the number of hairs being large and the midrib is greenish.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1923-24	126	13	36·2	3,641
1924-25	165	16	41·1	4,798
1925-26	156	18	44·3	5,823
1926-27	81	10	46·0	3,284

This type gives less tillers after harvesting and suffers badly in dry years.

Flowering habit and character of inflorescence. This is rather a late flowering type. The average number of days from germination to flowering was :—1923-24—118 days ; 1924-25—105 days ; 1925-26—111 days ; and 1926-27—111 days. The last is not comparable. The shrivelled anthers are yellow.

Earhead characters. The heads are less compact than of *Budh Perio* 7, are of moderate size, with basal spikes projecting. The length of rachis is shorter than that of *Budh Perio* 7 and has been as follows : —1923-24—8·8 cm. ; 1924-25—8·9 cm. ; 1925-26—9·2 cm. ; 1926-27—8·9 cm. The number of rachis branches is less than *Budh Perio* 7 but greater than *Althan Deshi* 6, while average number per 10 cm. length is less than in *Althan Deshi* 6, indicating less compactness of the heads. It has been as follows :—1923-24—88 ; 1924-25—83 ; 1925-26—90 ; 1926-27—95. The number of seeds per branch is low, being only greater than in *Budh Perio* 7, as follows :—1923-24—19·4 ; 1924-25—22·6 ; 1925-26—21·1 ; 1926-27—25·6.

Seed characters. The grains are pale yellowish, flat, and big with good lustre and are uniform. It is less hard than in previous strains. These grain characters, *viz.* size and lustre, are maintained in dry year, but when sown late deteriorate ; 1,000 grains weighed 37·3 grams in 1923-24 ; 15·3 grams in 1924-25 ; 33·9 grams in 1925-26 ; and 19·2 grams in 1926-27. The average grade has been in 1923-24—1·47 mm. ; in 1924-25—4·49 mm. ; in 1925-26—1·37 mm. ; and in 1926-27—4·62 mm.

(5) Budh Perio 53.

This was selected in 1923-24 and was grown from selfed heads since then.

Habit of growth and vegetative characters. This type is shorter than *Budh Perio* 7 but has the thickest stems. The leaves are large and the leaf area per plant is in some years the highest among all our strains. The leaves are sparsely hairy and are drooping. The midrib is greenish.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1925-26	154	19	14·0	5,563
1926-27	130	14	60·1	6,002

Flowering habit and character of inflorescence. It has the late flowering habit, though it ripens at the same time as other strains. The average number of days from germination to flowering was 119 days in 1925-26 and in 1926-27 was 138. The shrivelled anthers are red. The stigma is also pinkish. The inflorescence when out from flag gives a flattened appearance on both sides.

Earhead characters. The heads are long, semi-compact and are the biggest among the compact and semi-compact types. The basal spikes are projecting. The length of rachis has been as follows:—1925-26—11·2 cm. and in 1926-27—11·5 cm. The number of rachis branches is very high. It is also very high per unit length of earhead, the number per 10 cm. length of rachis has been 85 in 1925-26 and in 1926-27, 113. The number of seeds per branch is small. It was 19 in 1925-26 and in 1926-27 it was 23·6.

Seed characters. The grains are whitish round plump and hard. The seed weight in ordinary seasons is heavier than that of the strain last described. 1,000 grains weighed 47 grams in 1924-25; 31·3 grams in 1925-26; and 57·8 grams in 1926-27. The average grade has been in 1925-26—4·30 mm. and in 1926-27—4·58 mm.

(6) Chapti 8.

The description of this type is the representative of the *Chapti variety.*

Habit of growth and vegetative characters. This type is of the same height as *Moni Timberwa* 7. However, the stem is the thinnest, being only thicker than *Selection* 10. The leaves are sparsely hairy. The tips of leaves are very sparsely hairy, and the hairs are seen towards the midrib. The midrib is greenish.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Leaf area per plant
	cm.		mm.	sq. cm.
1923-24	143	14	38·2	3,905
1924-25	163	16	38·3	4,147
1925-26	134	17	37·4	4,270
1926-27	91	11	43·0	3,346

Flowering habit and character of inflorescence. The period for flowering is the same as that of *Budh Perio* 7 or little late. The average number of days from germination to flowering was: 1923-24—116 days; 1924-25 --105 days; 1925-26—111 days; and 1926-27 145 days. The shrivelled anthers are whitish yellow. The number of pedicelled flowers with anthers is very low, even less than in *Budh Perio* 10. There are no hermaphrodite flowers with two staminate flowers attached. The peduncle is curved.

Earhead characters. The heads are of moderate size and are semi-compact as though they are compact at the base, they are slightly loose at the top and broad and bulging at the base. The length of the rachis is the shortest among all strains and has been as follows: -1924-25 and 1925-26 7 7 cm. and 1926-27—8·4 cm. The number of rachis branches is al o the least among all strains. However, as the rachis length is short, the numbe of branches per unit length seem

moderate. It has been per 10 cm. of rachis length :—1924-25—71 ; 1925-26—75 ; 1926-27—80 cm. The number of seeds per branch is low and has been as follows : —1924-25—25 5 ; 1925-26—20 ; and 1926-27—22·7.

Seed characters. The grains are milky white, flat and big and soft. It has the heaviest grains nd the weight is comparatively maintained whatever may b the nature of the seasons. 1,000 grains weighed 53·9 grams in 1924-25 ; 39·3 grams in 1925-26 ; and 51·7 grams in 1926-27. The average grade has been in 1923-24—4·62 mm. ; in 1924-25 -4·52 mm. ; in 1925-26—4·49 mm.; and in 1926-27 —4·99 mm.

(7) Telia Chapti 24.

This type is a selection from the variety " *Telia Chapti* " which has flat seeds, yet they are hard and pearly yellow, and fetches the highest price.

Habit of growth and vegetative characters. This type is dwarf in habit, being even shorter than *Ulthan Deshi* 6. The stems are thick ; it looks very leafy as the leaves are broad. The leaves are nearly glabrous and have greenish midrib.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1925-26	122	18	41·4	4,863
1926-27	115	13	54·8	5,416

Flowering habit and character of inflorescence. It is late in flowering. The average number of days from germination to flowering was 120 days in 1925-26 and 145 days in 1926-27. The shrivelled anthers are red. The peduncle is curved.

Earhead characters. The heads are of moderate size. They are compact at the base but rather loose at the top. The length of rachis is long and has been 10·3 cm. in 1925-26 and 1926-27– 10 6 cm. The number of rachis branches is moderate but it is much decreased in a dry season. The number per 10 cm. length of rachis is the lowest among all compact and semi-compact types and has been 65 in 1925-26 and 80 in 1926-27. The number of seeds per branch is the highest and has been 23·7 in 1925-26 and in 1926-27, 31·4.

Seed characters. The grains are pearly yellow, very flat, big and hard. They are heavy in weight, but it is much affected in a dry season ; 1,000 grams weighed 48·1 grams in 1924-25 ; 27·2 grams in 1925-26 ; and 53·6 grams in 1926-27. The average grade has been 3·99 mm. in 1925-26 and in 1926-27—4·92 mm.

(8) Telia Chapti 26.

This was selected from the local variety in the same way as the strain last described.

Habit of growth and vegetative characters. This type is moderate in height and the stems are thinner than those of *Telia Chapti 24*. The tallness is due to long internodes. The leaves are rather small and the leaf area per plant is rather low. They are glabrous and the midrib is greenish.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm		mm	sq. cm
1925-26	138	18	39.1	4,172
1926-27	122	13	32	4,677

Flowering habit and character of inflorescence. It is late in flowering like *Telia Chapti 24*. The average number of days from germination to flowering was 120 days in 1925-26 and in 1926-27 115 days. The shrivelled anthers are red.

Earhead characters. The heads are semi-compact bulging a little above base. Peduncle is inclined. The length of rachis is very long and has been 11.2 cm. in 1925-26 and 10.5 cm. in 1926-27. The number of rachis branches is rather high. The number per 10 cm. length of rachis has been 67 in 1925-26 and in 1926-27 96. The number of seeds per branch has been 16.8 in 1925-26 and in 1926-27 29.

Seed characters. The grains are flat, hard, pearly yellow and are more plump than in *Telia Chapti 24*. The seeds are lighter in weight than in *Telia Chapti 24*. 1,000 seeds weighed 17 grams in 1924-25, 32.3 grams in 1925-26 and 16.6 grams in 1926-27. The average grade has been 4.15 mm. in 1925-26 and 4.59 mm. in 1926-27.

(9) Sholapuri 1.

This type is the typical representative of the lax group of Surat *jowars*.

Habit of growth and vegetative characters. This type is taller than the general variety due to the longer internodes particularly the top five, though the latter are shorter than those of *Sholapuri 15*. The stem is rather thin. The leaves are long but narrow. They are practically glabrous at the tip; the midrib is white which is almost universal in the variety and thus the stem is pithy.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm		mm	sq. cm
1923-24 .	127	[illegible]	35.0	3,122
1924-25 . .	179	16	39.4	4,694

Flowering habit and character of inflorescence. It is as late as *Moni Timberwa* 7. The average number of days from germination to flowering was :—1923-24—121 days; 1924-25—105 days; 1925-26—107 days. The shrivelled anthers are typically red. Pedicelled flowers with anthers were altogether absent in 1926-27—quite a novel feature. The peduncle is long and straight generally.

Earhead characters. The heads are loose, big and cylindrical. The length of rachis is exceptionally long, common to the lax group. It was 14·2 cm. in 1923-24 and 13·6 cm. in 1924-25. The number of rachis branches is low. The number per 10 cm. length of rachis is very low and has been 47 in 1923-24 and in 1924-25. The number of seeds per branch is high and has been 24·8 in 1923-24 and 26·5 in 1924-25.

Seed characters. The grains are dull whitish, small, round, plump and hard with wavy constrictions on the seed surface. 1,000 grains weighed 33·6 grm. in 1923-24 and 39·5 grm. in 1924-25. They are the lightest among all strains. The average grade has been 4·28 mm. in 1923-24 and 4·44 mm. in 1924-25.

(10) Sholapuri 18.

Habit of growth and vegetative characters. This type is medium in height, though the top five internodes are very long. It has a low leaf area per plant. The leaves are sparsely hairy and have a white midrib. The stems are pithy.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1925-26	155	18	43·2	4,764
1926-27	124	12	49·7	4,372

Flowering habit and character of inflorescence. It is late in flowering. The average number of days from germination to flowering was 116 days in 1925-26 and 146 days in 1926-27. The shrivelled anthers are yellow, rather uncommon for the variety. The peduncle is rather short.

Earhead characters. The heads are loose, very long, tapering and big. The length of rachis is the longest among all strains and was 15·7 cm. in 1925-26 and 15·1 cm. in 1926-27. The number of rachis branches is very low, being only greater than in *Chapti* 8; while the number per 10 cm. length of rachis is the lowest and has been 45 in 1925-26 and 56 in 1926-27. The number of seeds per branch is as follows :—1925-26—21·9 and in 1926-27—28·5.

Seed characters. The grains are pale yellow, hard, plump and round; 1,000 seeds weighed 46·6 grams in 1924-25; 32·1 grm. in 1925-26; and 47·1 grams in

1926-27. The average grade has been in 1925-26—4·23 mm. and in 1926-27—4·4 mm.

The ideal Jowar plant for Surat.

The study, of which an account has been given, has led to a very clear conception of the type of *jowar* plant which should be arrived at under the conditions of the Surat District. Naturally, the prime necessity is a high yield of grain, but there are certain associated characters which make a plant specially suitable under the conditions.

Habit of growth. A tall plant having long internodes is desirable, with a large number of nodes and hence a large leaf surface. Shorter internodes in the upper part of the stem seems associated with compact heads. Such plants, too, do not lodge, whereas plants which have longer internodes in the upper part of the stem tend to have loose heads, and also tend to lodge, as is the case with all *Sholapuri* strains, and this is a distinct objection against this variety.

Leaf area per plant. While a large leaf area is closely correlated with high yield yet, on the whole, it appears that types with medium leaf surface like *Althan Deshi* 6 are to be preferred, taking all seasons together. *Moni Timberwa* 7, which has the largest leaf surface among the selections described, does not fare well particularly in dry seasons.

Wax on the stems. The presence of wax on the stem is considered by many workers to be a sign of drought resisting character, and certainly the selection *Althan Deshi* 6, in which it is largely developed, does the best in a dry season. The relation of wax to drought resistance is not yet, however, clear. As to the advantage or disadvantage of hairiness on leaf, little can be said though there is a general belief that the glabrous types (like *Chapti*) do best in moisture retentive soils, and the hairy ones like *Perio* and *Sholapuri* where there may be water deficiency.

Habit of leaves. In dry years, all *Jowar* types make their leaves nearly erect in the middle of the day, and in some strains this is very highly developed. It is a desirable character to encourage on soils where moisture is likely to be short The *Vani* variety has this character to a marked extent.

Colour of leaves. After two or three months' growth, a dark green colour is always considered as a sign of healthy robust growth. It should always be preferred to a lighter colour of the leaves.

Flowering habit. The *Jowars* of the Surat District are generally late in flowering, and a type flowering and ripening earlier, when planted at the usual time would be of considerable advantage. *Sholapuri* types are capable of being planted late, but if planted at the usual time, they do not flower earlier than some of the *Perio* selections. The general late flowering habit in Surat appears to be due to the fact that if the peduncle emerges during August and September, it is very likely to be attacked by insect pests, especially by the borers (*Chilo simplex* and *Sesamia inferens*). How to meet the demand for an early

flowering type, and yet one which will avoid these pests, is not yet quite clear. Very markedly late flowering types, even though they ripen at the same time as others, are not desirable.

Types having recessive characters in the inflorescence – such as yellow anthers – are desirable, so as to make it easy to keep the types pure.

Earhead. Cultivators prefer compact headed types of *jowar*, as they are generally believed to be heavy yielders. This belief does not appear to be entirely well founded as *Budh Perio* 53 and *Telia Chapti* 26, which are semi-compact types, and *Sholapuri* 18, which is a loose type, are high yielders. Compact headed types usually give a grain very much more mixed in size. A semi compact head is, on the whole, to be preferred.

The loose headed types are supposed, also, to be less attacked by birds, but, on the other hand, all these have a tendency to lodge.

They also have a larger amount of cross-fertilization and this is not a desirable character.

In semi-compact headed types, the head should be big, as otherwise low yields may result.

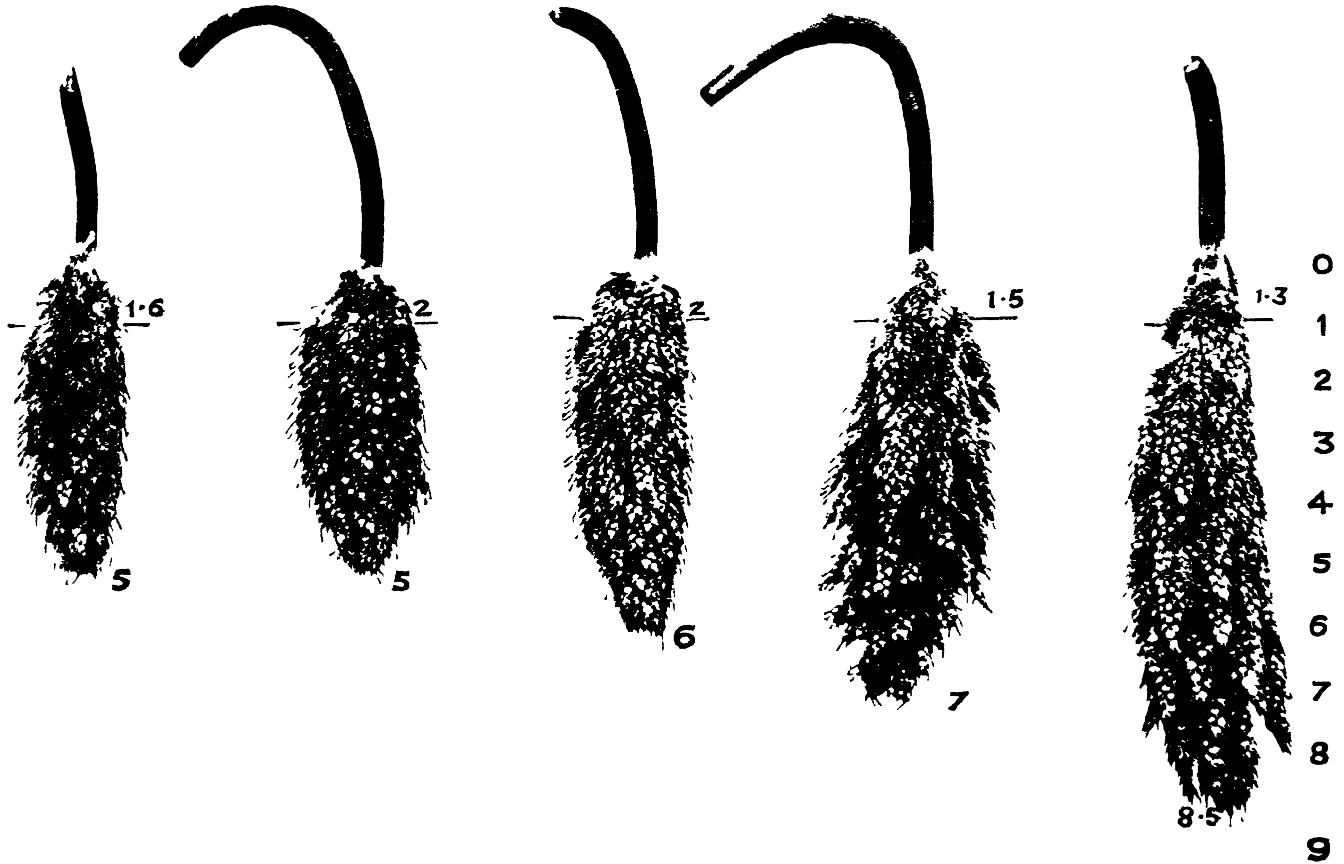
Grain. The seeds should be large and dense. Bigger grain is always preferred by consumers, and such large grains are usually also flat. Flat and hard types, in our experience, have not maintained their character well in years of drought. Soft grains have the disadvantage of being more easily attacked by weevils.

As to colour, very white grains are usually preferred by Parsis and not by others. Generally, the types with pearly yellow colour with good lustre are preferred. Such a kind is the *Moni Timberwa* 7 strain, but it does not maintain this character when sown late.

Straw. (*Kadbi*). Jowar straw should not be hollow. As the character of the straw in this respect can be noticed from the colour of the midrib of the leaf such types can be eliminated A green leaf midrib means desirable straw. Other things being equal, the *Kadbi* should be thin, though heavy grain yielders are almost invariably thick stemmed types. Comparatively thin straw can be found in combination with moderately good yield in *Althan Deshi* 6 and it should not be impossible to combine the two desirable characters.

Acknowledgments. We are under very considerable obligations to Dr. H. H. Mann, Director of Agriculture, Bombay Presidency Poona, who guided the work and gave very valuable suggestions during the course of study.

PLATE I.



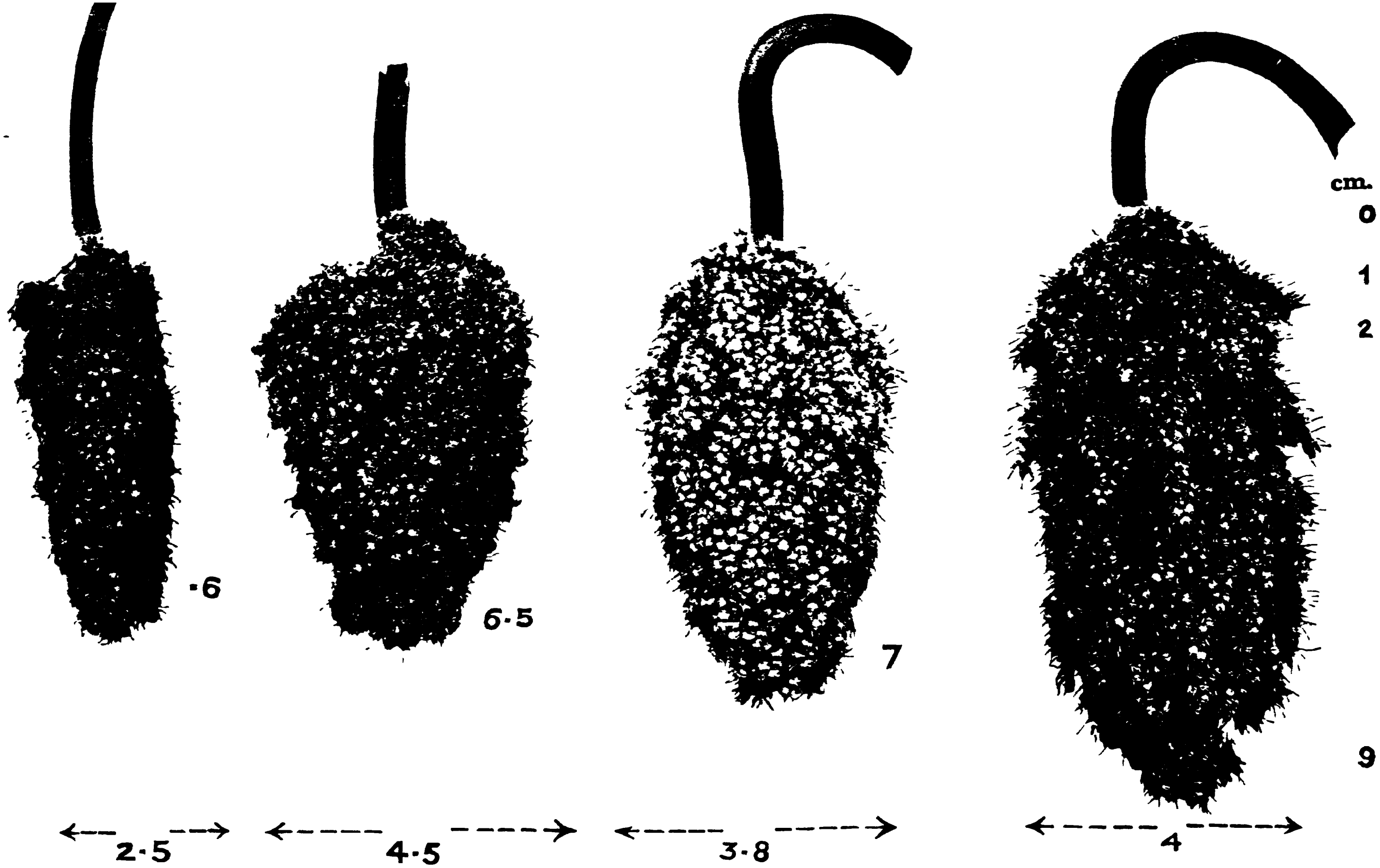
Showing differences in shape and size of inflorescence as revealed by the length of rachis and greatest breadth of inflorescence in cm.

From right 1 and 2. *Sholapuri* 1 and 21 (respectively): At the base they are narrow with very few branches. Rachis long and branches sparse and long. There is a regular gradation as to the breadth showing the looseness.

3. *Budh Perio* 53: Rachis intermediate in length. Also intermediate in looseness (*i e* in greatest breadth)

4 and 5. *Moni Timberua* 7 and *Althan Deshi* 6: Rachis less in length, but in the former more bulging at the base and not as compact as in the latter.

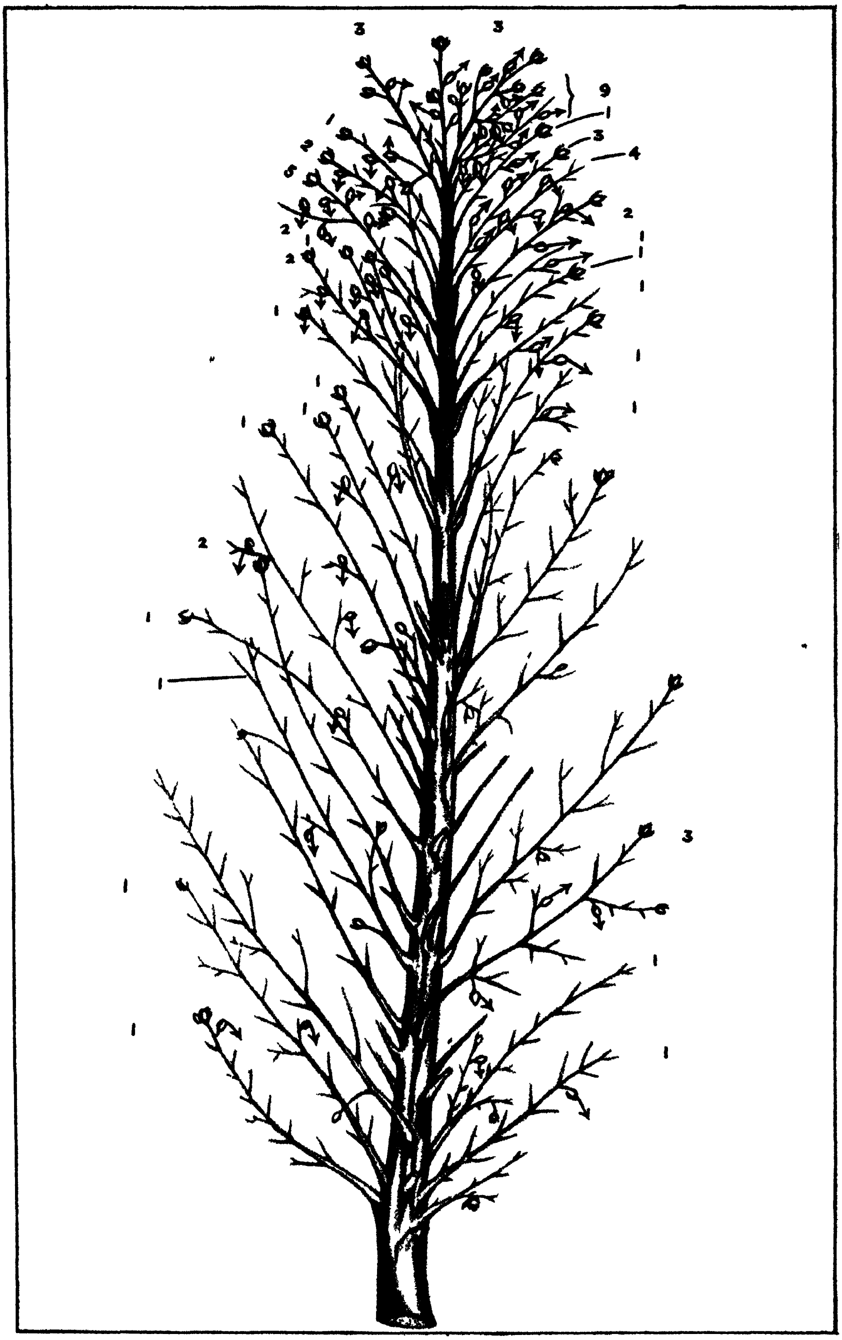
PLATE II.



Showing difference in mature heads of *Perio* types (from right):—

1. *Budh Perio* 53: Big, semi-compact, *i.e.* long rachis and greater breadth, *i.e.* 4 cm.
2. *Moni Timberwa* 7: Big head, more compact than *Budh Perio* 53 with no bend at the top as seen in *Budh Perio* 7.
3. *Budh Perio* 7: Compact and blunt head with a characteristic narrow bend just below the tip (in fact bulging) as represented by the greatest breadth 4·5.
4. Selection 40: Semi-compact, uniformally broad all along, representing a cylinder.

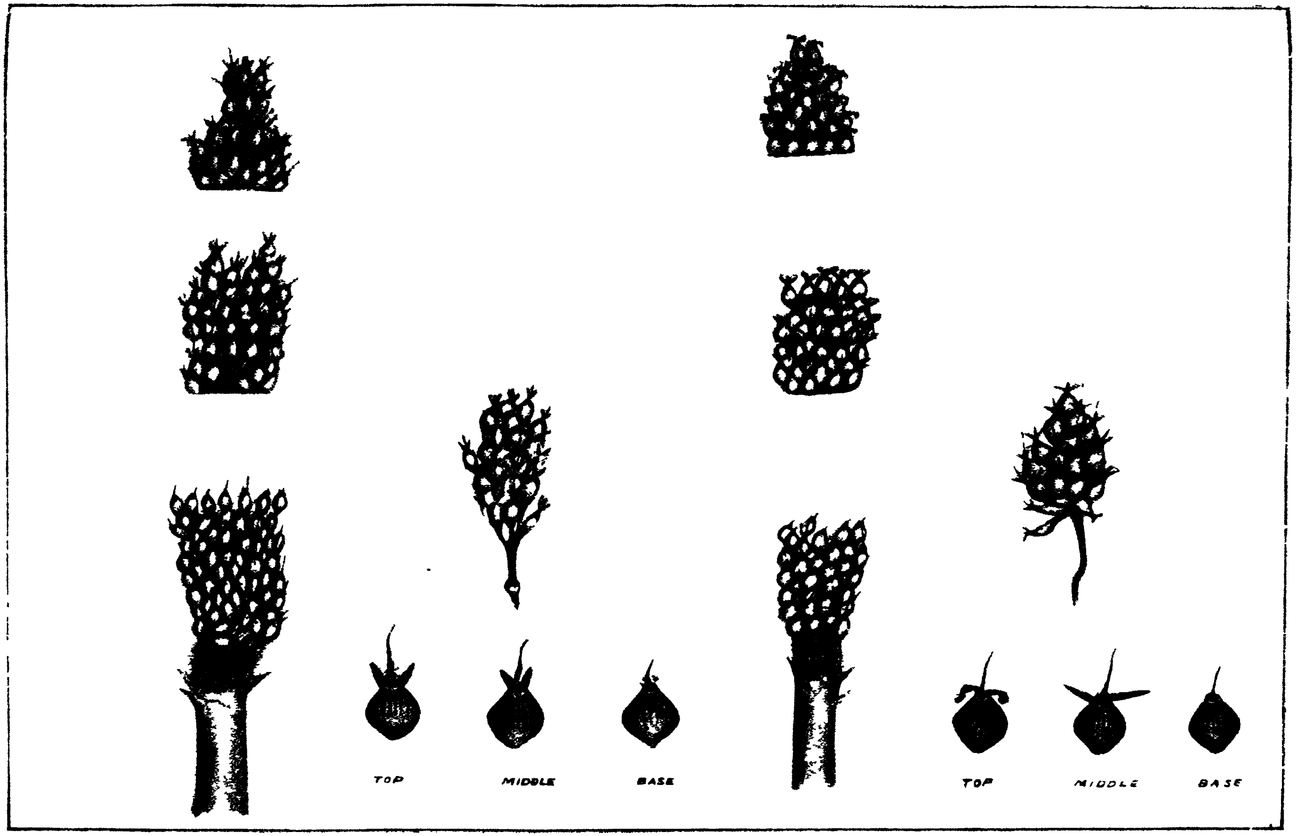
PLATE III



Showing how the male flowers or empty spikelets are distributed in *Budh. Perio,* No. " 40."

Only a few spikelets are shown out of a large number The arrow heads show the pedicelled male spikelets. The lines round hermaphrodite spikelets represent empty pedicelled spikelets. Figures show the number of pedicelled staminate flowers on each branch. Most of the staminate flowers are in the upper portion and are also at tips of branchlets.

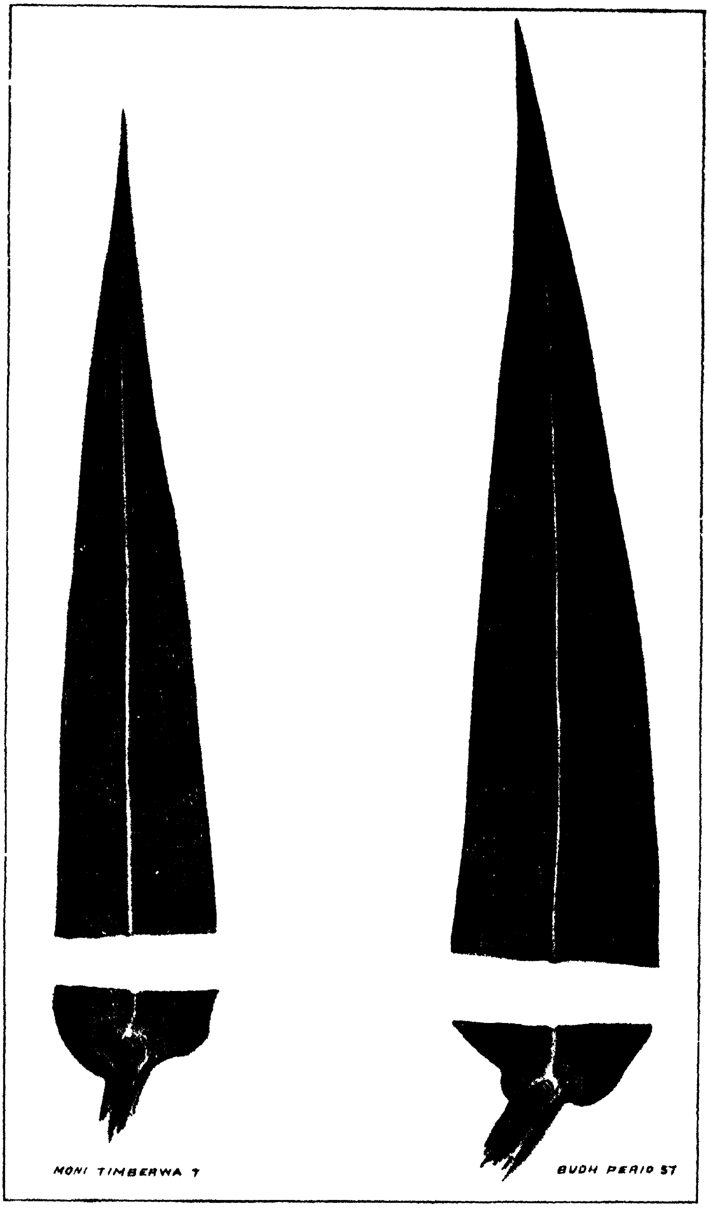
PLATE IV.



Showing difference in the emergence of styles and anthers when most flowers open on a single day.

Left to right :—

No. I. Striga resistant type :—*Top.*—Anthers shrivelled up seen (styles not seen, *i.e.*, shrivelled up). *Middle.*—Styles and anthers almost on level and bent much (styles) and anthers coming out prominently. *Base.*—Stigma just coming out and no anthers. No. II. *Althan Deshi* 6 :—*Top.*—Dried up feathery stigmas with yellow anthers out. *Middle.*—Feathery long styles bent slightly with anthers protruding at the base of the stigma. *Base.*—Flowers without any feathery ends.

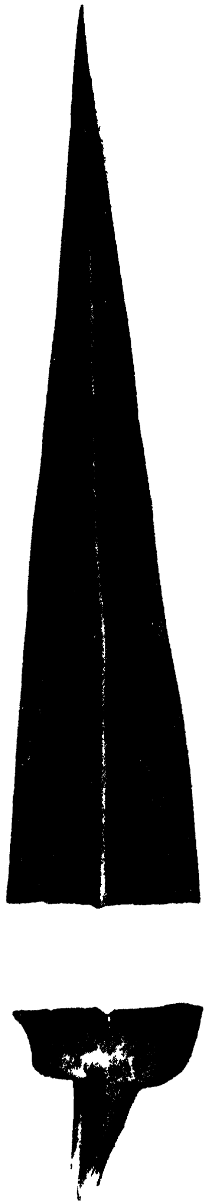


The hairs are magnified in the drawings to make them more visible :—

(3) Moni Timberwa 7 : " Very hairy Type." The hairs are profusely prominent, long and persistent. On an average the hairs are found on the length of 23 cm. out of the total length of 51 cm. They are fading to some extent from the midrib as we see downwards.

(4) Budh Perio 57 : Hairy Type. On an average the hairs are seen on the length of 21 cm., out of total length of 69 cm. though extremely minute hairs are found almost all over, *i.e.*, not quite glabrous surface. They are sparse round midrib as we see downwards towards the midrib.

CHAPTI 8



BUDH PERIO 9

The hairs are magnified in the drawings to make them more visible. 1 *Chapti* 8 "Sparsely hairy type" On an average, the hairs are seen on the length of 16 cm. out of total length of 58 cm Hairs are very minute as compared with other strains but dense on the surface of 16 cm. at the top. They are fading from the midrib or away from the midrib downwards towards the middle. 2. *Budh Perio* 9. On an average the hairs are seen only on the length of 13 cm out of the total length of 56 cm. Extremely minute hairs are seen almost all over the leaf The hairs are found away from the midrib towards the middle of the leaf for a very short distance.

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Memoirs of the Department of Agriculture in India

Studies in Indian Chillies

(1) The Types of Capsicum

BY

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AND

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DESCRIPTION OF THE PLATES

STUDIES IN INDIAN CHILLIES.

(1) THE TYPES OF CAPSICUM.

BY

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(Received for publication on 26th April 1928.)

I. Introduction.

Chillies constitute one of the most valuable of the minor crops of India. No separate statistics of production and acreage are available, the figures for this crop being included in the official returns under the heading of "Condiments and spices." In Madras, the province with by far the largest production of chillies, the area under "condiments and spices" is estimated at about 700,000 acres of which probably about 300,000 acres are under chillies. The crop is also cultivated fairly extensively in Northern India where in Bihar it forms a profitable alternative to tobacco. In Gangetic India generally it is a cold weather crop, transplanting taking place about September and harvesting about January-February. In the North-West, however, the season is different and in the Peshawar valley chillies are transplanted in April and harvested about the end of October.

The bulk of the chillies grown in India are consumed locally and the export trade is small but steady, being in the neighbourhood of 16 million pounds a year. About 44 per cent. of the total exports go from Bengal and 38 per cent. from the Madras Presidency. The largest customers are Ceylon and the Straits Settlements, which countries absorb over 80 per cent. of the total exports.

The present investigation was started in 1924 with the object of isolating the different types of chillies growing in India as a preliminary to the study of the inheritance of characters in the crop and with the possibility of obtaining types of chilli which would prove more valuable in yield and quality than those commonly cultivated at present. Some 52 types are described and classified, of which three are foreign varieties and the remainder are Indian. The biology of the flower has been studied and the authors desire to acknowledge the assistance received from Mr. R. B. Deshpande, post-graduate student in the Section, in this portion of the work.

II. Biology of the flower.

The genus Capsicum belongs to the Solanaceae. The flowers [1, 2] are pedicelled axillary, solitary or 2-3 together. Calyx campanulate, sub-entire or minutely 5-toothed much shorter than fruit. Corolla rotate; lobes five, valvate in bud. Stamens 5, attached near the base of the corolla; anthers not longer than the filaments, dehiscing longitudinally. Ovary 2, rarely 3-celled; style linear, stigma subcapitate.

1. Bending of the pedicel.

In the young stage when the bud is small the pedicel is straight. As the flower bud becomes older the pedicel elongates and becomes bent so that the bud before opening takes up a more or less inverted position. In the varieties of chillies which possess pendent fruits, the bend in the pedicel occurs near the base and the flower is completely inverted and pendent (Text Fig. 1, Type 25), but in the case of types with erect fruits the bend takes place near the top of the pedicel (Text Fig. 1, Type 21) and the flower may be either pendent or in a more or less horizontal position. When the bend is near the base of the pedicel, it is permanent and the fruit is therefore pendent (Text Fig. 1, Type 25); but when the bend is near the top of the pedicel, it tends to straighten out after fertilisation and as a result the fruit becomes almost erect (Text Fig. 1, Types 21, 22). In this latter case the time taken in assuming the erect position is from 8 to 19 days after flowering.

2. Flowering.

In nearly all crops the time at which the flowers open varies with the diurnal temperature. On warm days and when there is little or no dew, the flowers open earlier than on cold and dewy mornings. Flowering begins in Bihar about September and is practically continuous throughout the cold weather up to February. Observations on the opening of flower buds were taken between the 19th November and 27th November 1927 and on the 13th January 1928; the climatic conditions during this period were as follows:—

Date	Temperature			Humidity	Rain
	8 A.M.	Maximum	Minimum	8 A.M.	
				Per cent.	
19th November 1927 . .	60·7	79·3	56·7	92	*Nil.*
20th November 1927 . .	61·1	79·9	56·9	96	*Nil.*
21st November 1927 . .	60·1	79·2	55·5	95	*Nil.*
22nd November 1927 . .	59·7	78·0	54·5	90	*Nil.*
23rd November 1927 . .	59·8	77·4	55·2	95	*Nil.*
24th November 1927 . .	58·3	78·5	53·9	91	*Nil.*
25th November 1927 . .	58·9	77·7	54·5	93	*Nil.*
26th November 1927 . .	63·0	79·4	57·6	92	*Nil.*
27th November 1927 . .	61·8	81·1	58·0	91	*Nil.*
13th January 1928 . .	49·8	73·8	42·9	95	*Nil.*

[1] Hooker, Sir J. D. Flora of British India, Vol. IV, page 238.
[2] Prain, Sir D. Bengal Plants, Vol. II, page 747.

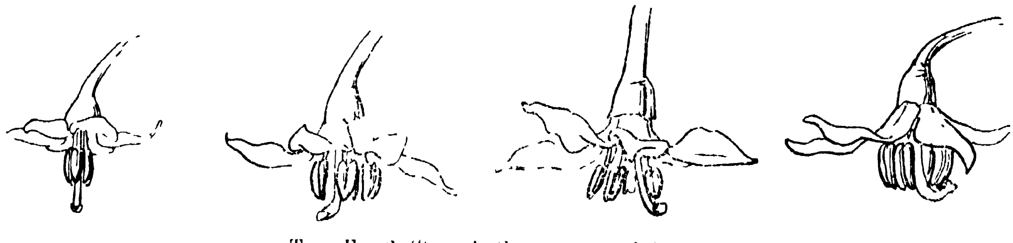
TEXT FIG. 1. A branch from Type 21 showing an erect mature fruit and stages in the assumption of the erect position from the bud to the fruit.
A branch from Type 22 showing how erect fruits may fall to a horizontal position.
A branch from Type 25 showing a pendent fruit and stages in the development of the fruit.

In November the buds begin to open at about 7.30 A.M. and continue opening up to 1 P.M., the majority of the buds however which open on any one day do so between 8 A.M. and 10 A.M. Those buds which open late in the day remain in a half opened state until the following day when they become fully open somewhat earlier than other flower buds which are opening for the first time on that day. Among 114 flower buds which were observed on the above mentioned dates in November, 7 became fully open between 7.30 and 8.30 A.M., 52 between 8.30 and 9.30 A.M.,

33 between 9-30 and 10-30 A.M., 14 between 10-30 and 11-30 A.M., 6 between 11-30 and 12-30 and 2 between 12-30 and 1-30 P.M. On the 13th January, however, out of 20 buds 3 opened between 12 noon and 1 P.M., 2 between 1 and 2 P.M., 6 between 2 and 3 P.M., and 9 buds became incompletely open but opened fully on the morning of the next day.

3. *Pollination.*

The style is generally straight and usually longer than the stamens, though on the same plant flowers with the style shorter than the stamens and flowers with the style about the same length as the stamens can be found. The length of the style and the fact that the flower is inverted renders it unlikely that self-fertilisation will take place unless the plant is agitated by wind. At the commencement of this research, when chilli plants were first bagged to procure selfed seed, it was found that seed setting under bags was very scanty. This was due to the fact that plants under bags were kept in an unnaturally close and fixed position; shaking the bags once a day at 2 P.M. resulted in abundant seed setting. In many varieties of chilli, a certain percentage of the flowers possess curved styles instead of straight styles; this shortens the distance between stigma and anther and at the same time places the stigma in a more favourable position for receiving the pollen. The examination of nearly 300 flowers in three different types showed that about one-third of the flowers had styles which showed varying degrees of curvature (see Text Fig. 2.). Self-fertilisation is, therefore, more probable in such flowers.



TEXT FIG. 2. Stages in the curvature of the style.

The anthers burst some time after the flower is open. Out of 37 flowers which were observed in November 1927, in 10 flowers the anthers burst half an hour after the flower had opened, in 8 flowers after an hour, in 5 flowers after $1\frac{1}{2}$ hours, in 3 flowers after 2 hours, in 3 flowers after $2\frac{1}{2}$ hours, in 4 flowers after 3 hours, in 2 flowers after 4 hours and in 2 flowers after 5 hours. The delay in the bursting of the anthers favours cross fertilisation and in fact in some flowers stigmas have been found covered with pollen before the dehiscence of the anthers has taken place. Bees and ants visit the flowers in moderate numbers.

The flowers remain open for two or three days and in Bihar do not close at night. The closing which is described by Shrivastava [1] as taking place in the Central Provinces was not observed at Pusa. The corolla generally drops within two or three days after the flower is fully open, but it may persist for a longer time. Out of 93 flowers which were observed in November 1927, the corolla fell in 2 flowers on the first day after the flower was fully open, in 26 flowers it fell on the second day, in 48 flowers on the third day, in 11 flowers on the fourth day, in 4 flowers on the fifth day and in 2 flowers on the sixth day. The fruit ripens in 2 to $2\frac{1}{2}$ months from the opening of the flower.

4. Cross-fertilisation.

It is evident from the above that in chillies both cross and self-fertilisation takes place and indeed that in nature there is probably, under suitable conditions, a considerable amount of crossing. Thus in 23 cultures, each culture being the progeny of a single plant which had been bagged, 21 cultures bred true to the parent type and 2 cultures showed splitting, while in 96 cultures of which the parents were not bagged only 21 bred true to the parent type and 75 showed splitting. As the different parent plants were grown in lines next to one another, the conditions were very favourable for making obvious the results of any natural crossing in the case of unbagged plants. The splitting in the case of the two cultures from bagged plants is, of course, to be attributed to the heterozygous condition of the parents.

The segregation of characters in these cultures suggests that in the fruit yellow colour and the erect habit are recessive to red colour and the pendent habit. The details of the cultures in which segregation into red and yellow and erect and pendent fruits took place were as follows:—

Parent Fruit red	Progeny		Total number of plants in culture
	No. of plants with yellow fruits	No. of plants with red fruits	
Culture No. 3 of 1927	7	11	18
,, ,, 4 of 1927	9	18	27
,, ,, 8 of 1927	14	13	27
,, ,, 6 of 1927	2	25	27
,, ,, 9 of 1927	10	8	18
,, ,, 10 of 1927	3	23	26
,, ,, 13 of 1927	3	15	18
,, ,, 14 of 1927	2	23	25
,, ,, 19 of 1927	14	13	27
,, ,, 41 of 1927	4	4	8
,, ,, 2 of 1928	3	14	17
Total	71	167	238

[1] Shrivastava K. P. Account of the Genus Capsicum grown in Central Provinces and Berar. *Bull,* 5, *Dept. Agri., Central Provinces,* 1916.

Parent Fruit pendent	Progeny		Total number of plants in culture
	No. of plants with erect fruits	No. of plants with pendent fruits	
Culture No. 7 of 1927	2	16	18
" " 39 of 1927	10	14	24
" " 5 of 1928	1	25	26
" " 18 of 1928	12	15	27
" " 22 of 1928	5	22	27
" " 23 of 1928	6	21	27
" " 26-1 of 1928	18	9	27
" " 28-1 of 1928	6	22	28
Total	60	144	204

III. Systematic.

(1) *General.*

Notwithstanding the wide-spread cultivation of the genus *Capsicum* in India the plant is almost certainly not indigenous in Asia but has its home in tropical South America where its cultivation is ancient and where it has been found growing wild on the banks of the Amazon and in eastern Peru. De Candolle [1] cites the fact that there is no name for chillies in Sanskrit and Chinese as evidence that this plant was not known to Asia until modern times. Had such a plant been native in the Old World, its cultivation would have spread rapidly and it would have had names in several ancient languages, whereas Greek, Latin, and Hebrew, like Sanskrit and Chinese, do not contain any name for chillies, and the Romans, Greeks, and Hebrews appear to have been unacquainted with this plant.

The classification of the genus *Capsicum* has been carried out in recent times by Roxburgh,[2] Hooker,[3] Prain,[4] Shrivastava [5] and Irish.[6] The first four authors described the various species of Indian chillies and the last named author worked with a large collection of different forms of *Capsicum* in the Missouri Botanic Garden. Early writers have described a large number of different species opinion varying greatly concerning the number of species and varieties. In a summary of previous systematic work with this genus Irish writes as follows:—

"Three varieties were figured by Fuchsius in 1542, thirteen by Gregorius in 1611, twenty by Parkinson in 1642 Thirty-five were mentioned by Morison in 1680

[1] De Candolle Alphonse Origin of Cultivated Plants. Second Edition, 1904, page 288.
[2] Roxburgh, W. Flora Indica, 1832, Vol I, page 573.
[3] Hooker, *loc. cit.* page 2.
[4] Prain, *loc. cit.* page 2.
[5] Shrivastava, *loc. cit.* page 4.
[6] Irish, H. C. Revision of Genus Capsicum. *Missouri Bot. Gard. Report* 9, 1898.

twenty-seven by Tournefort in 1700, eighteen by Miller in 1731, though in 1771 after the binomial system had come into use, he gave but ten specific names. Linnaeus in the first edition of his Species Plantarum (1753) records two species and in his Mantissa (1767) recognises two additional ones. In the fourteenth edition of his Systema Vegetabilium, edited by Murray (1789), one new species is given, and in the Willdenow edition of the Species Plantarum (1797) still another is added. Romer and Schultzes in their edition of the Systema Vegetabilium (1819), add what they considered fifteen good and three doubtful species to those already described since the time of Linnaeus. Of these fifteen, only one was given for the first time by them all the others having been previously named by various botanists since Willdenow's edition. In 1832 Fingerhuth recognized twenty-five accepted species, together with seven requiring further examination, and twenty-eight botanical varieties, three of the species and most of the varieties being named by him. In 1846 Sendtner recorded ten species and numerous varieties as occurring in Brazil alone, he having named seven of the species. In 1852, Dunal recorded fifty accepted species, of which eleven were described for the first time, together with many varieties, and eleven species requiring further examination, besides three doubtful ones."

The Index Kewensis recognises fifty-four specific names, out of ninety which have been given, but modern authorities generally consider that there are only a few species in the genus. Roxburgh describes 6 species *C. purpureum* R., *C. annuum* Willd., *C. grossum* Willd., *C. frutescens* Willd., *C. minimum* R., and *C. cerasiforme* Willd. Of these six species the last named, *C. cerasiforme* has globular fruits and *C. minimum* has the peduncles in pairs; the remainder have more or less elongated fruits with solitary peduncles. Hooker reduces the number of Indian species to three—*C. frutescens* Linn., *C. minimum* Roxb., and *C. grossum* Willd. The form *cerasiforme* is given as a variety of *C. grossum* and is stated to be rarely cultivated in India; we have, however, found that it is the predominant chilli of the North-West Frontier Province. Both Irish and Prain still further reduced the number of species to two—*C. annuum* Linn., and *C. frutescens* Linn. The latter species has the peduncles in pairs and is synonymous with the *C. minimum* of Roxburgh and Hooker. The species *C. annuum* Linn. is divided into a number of varieties which include all the other forms, *C. purpureum*, *C. grossum*, *C. cerasiforme*, etc. of Roxburgh and earlier writers. The list of species and varieties described by Irish and Prain is as follows :—

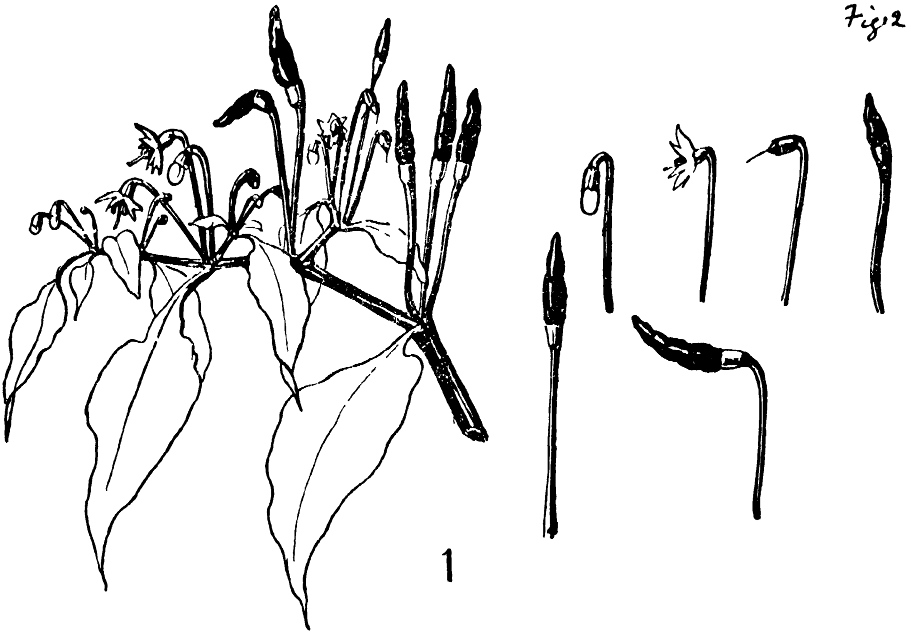
IRISH	PRAIN
C. frutescens.	*C. frutescens.*
C. annuun conoides.	,, ,, var. *baccata.*
,, ,, *fasciculatum.*	*C. annuum*
,, ,, *acuminatum.*	,, ,, var. *acuminata.*
,, ,, *longum.*	,, ,, ,, *abbreviata.*
,, ,, *abbreviatum.*	,, ,, ,, *grossa.*
,, ,, *cerasiforme.*	,, ,, ,, *cerasiformis.*
,, ,, *grossum.*	,, ,, ,, *nigra.*

(2) *The Differentiating Characters.*

Different authors have attached different degrees of importance to the morphological characters on which the taxonomic divisions of the genus are based. Generally the shape of the fruit and the nature of the calyx are taken as two of the most reliable differentiating characters. The erect or pendent character of the fruit is not a satisfactory criterion for a main taxonomic division within the genus as both types occur within different varieties. The morphological characters used in the present paper for the separation of the various types are as follows:

1. *Number of pedicels in the axil* (Text Fig. 3, Type 1).

Fig. 2



1

TEXT FIG. 3. A branch of Type 1 showing more than one pedicel in an axil and stages in the development of the erect fruit.

The branching of chillies simulates dichotomy. At the point of branching there is generally a single terminal pedicel bearing a flower bud, but in a few somewhat rare types the pedicels are not solitary, two or even three arising at the same place. This character has been taken as the first main distinction in our classification and serves to separate the species "*frutescens*" from the species "*annuum*." The present writers are in agreement with Prain and Irish in making these the only two species within the genus.

2. *Flower colour.*[1]

Most of the varieties have white or dirty-white flowers, in two types, however, the flowers are greenish-white and in one they are purple or splashed with purple colour.

3. *Shape of the fruit.*[2]

Fruits may be divided into "globular" and "not globular." The latter may be any shape from elongated finger shaped forms to conical irregular forms nearly as broad as they are long. The globular fruited forms are classed by Prain in the variety "*annuum* var. *cerasiformis*" and we have adopted this nomenclature in the case of the globular forms with small fruits. We have, however, found in our collection some large fruited forms in which the fruits although globular can hardly be classed as "cerasiformis." As in these large fruited varieties the surface of the fruit is corrugated we have named them "*annuum* var. *rugosa*." In addition to the division into fruits "globular" and "not globular" Prain further divides the latter group into "berries tapering much longer than broad" and "berries not much if at all longer than broad, usually obtuse." We have not found this a reliable criterion and have not, therefore, used this character at this point in the classification, but at a later stage we have classified fruits as long, medium in length and short.

4. *Nature of the calyx.*

The calyx may or may not enclose the base of the fruit. This character is used by Prain and by Irish and we have found it a good and reliable criterion. In varieties with thin fruits the calyx usually encloses the base of the fruit like a cup but in forms with thick fruits the base of the fruit is generally broader than the span of the calyx which therefore forms a flat green disc at the base of the fruit. In rare cases when the diameter of the calyx is about equal to that of the base of the fruit it is difficult to decide whether the calyx is slightly enclosing the base of the fruit or not; in such doubtful cases an examination of the largest fruits on the plant will always show that the calyx is really not enclosing the base of the fruit.

The four characters mentioned above furnish the basis on which the separation of the different types is made; all have been used by previous authors and the system followed in this paper agrees very closely with that used by Prain.

5. *Shape of transverse section of the fruit.*

The transverse section of the fruit may be circular, quadrate, corrugated, or irregularly angular.

6. *Position of the fruit.*[3]

As previously described (page 60) fruits may be either pendent or erect. In some erect varieties in which the fruits are very heavy, the fruits tend to assume a

[1] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 243.
[2] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 244.
[3] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 289.

horizontal position (Text Fig. 1, Type 22) when mature; the true erect nature of such fruits can be seen from inspection of the younger fruits. The erect or pendent position of the fruit is a good distinguishing character, but it cannot be used very early in the classification as erect and pendent fruited types can be found in many varieties.

7. *Colour of the fruit.*

The colour [1], [2] of the mature fruit is either red or orange but that of the immature fruit may be white, light green, green, dark green or purple. The majority of fruits are some shade of green when young and in a number of the types the green becomes marked with purple as the fruit develops. The amount of purple which is developed varies considerably in different types, it is generally most marked on the side of the fruit which is towards the sun. In one of our varieties (*C. annuum* var. *nigra*) the immature fruit is entirely purple, and indeed in this type the purple colour is spread over the whole plant; the fruit, however, is red when mature. In all types the purple colour changes more or less to green again as the fruit approaches maturity finally becoming red or orange coloured when ripe. The presence or absence of purple colour in the fruit, and the degree of its development, has been found a useful minor differe tiating character.

The ripe fruit is either red or orange and the two colours are easily distinguished one from the other. There are of course several grades of each colour and these are difficult to distinguish, particularly in the case of old and completely mature fruits in which the colour deepens considerably with exposure to the sun.

8. *Size of the fruit.*

The ratio of length to breadth in the fruit was not found by us to be a useful differentiating character and as a point of minor distinction we have classified fruits as short (up to 4 cm. long), medium (from 4 to 7 cm. long) and long (above 7 cm.).

9. *Surface of the fruit.*

The surface of the fruit is generally smooth in the fresh state but in all fruits a certain amount of shrinkage, and resulting wrinkling of the surface, takes on drying. In some types, however, depressions occur even in the fresh state and in the case of long thin fruits this wrinkled character has been found useful in separating minor types.

10. *Apex of the fruit.*

The apex of the fruit is pointed (acute) in some types and blunt in others. In a few special cases (Types 14, 15, 16 and 17) it is more or less lobed with a depression in the centre.

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[1] Halsted, Byron, D. Colors in Vegetable Fruits. *Jour. of Heredity*, Vol. IX, page 22, 1918.
[2] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 246.

11. *Flesh of the fruit.*

The inner portion of the wall of the fruit, beneath the skin, is called the flesh. In some types the flesh is very thin, and in others it is very thick, the two kinds can be easily distinguished and this has been used as a differentiating character by some writers; it is not so used in this paper.

12. *Maturity.*

Types are classed as early, intermediate, late and very late.

13. *Colour of the foliage.*

The different types vary as regards the greenness of their foliage; we have classified them as dark green, green and light green.

14. *Height of the plant.*

Types having a height of less than 40 cm. have been classed as short, from 40 to 60 cm. have been classed as medium in height, and above 60 cm. have been called tall.

15. *Character of the stem.*[1]

The stem is angular when young becoming circular in cross section as it gets older. The colour is at first green which becomes streaked with grey as cork is formed; in some varieties small patches of purple colour are developed in the stem particularly in the axils of branches and leaves. Irish states that the species *frutescens* and *cerasiforme* have stems which are much swollen at the node but the forms which we have classified as *frutescens* are scarcely swollen at all and forms which we have placed in *cerasiforme* are only slightly swollen. Almost all our types show some degree of swelling at the node, but we do not consider that this character affords a sound differentiating basis and we have not used it.

(3) *Key to the Types of Capsicum.*

Pedicels 2 or more (*C. frutescens*)—
- Unripe fruits green . . . . Type 1
- Unripe fruits white . . . . Type 2

Pedicels solitary (*C. annuum*)—
- Flowers purple (*C. annuum* var. *nigra*) . . . . Type 3
- Flowers white.
  - Fruits globular, large, irregular in transverse section, pendent (*C. annuum* var. *rugosa*)—
    - Fruits completely corrugated, broader than long, apex very broad . . Type 4
    - Fruits corrugated at base only, medium in size, flattened at top with distinct depression at the base of style, broader than long . . . . Type 5
  - Fruits globular, small, circular in transverse section (*C. annuum* var. *cerasiformis*)—
    - Fruits pendent, red, small, not corrugated, hard, symmetrically globular, breadth equal to length (*C. annuum* var *cerasiformis pendula*)—
      - Leaves light green . . . . Type 6
      - Leaves green . . . . Type 7
    - Fruits erect, orange, small, with distinct apical point (*C. annuum* var. *cerasiformis erecta*) . . . . Type 8

[1] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 242

Fruits elongated—

- Calyx not embracing the base, fruits generally broad—
  - Fruits circular in transverse section—
    - Fruits short (up to 4 cm.) (*C. annuum* var. *abbreviata*)—
      - Fruit apex acute, leaves dark green . . . . . . Type 9
      - Fruit apex blunt, leaves light green . . . . . . Type 10
    - Fruits medium in length (from 4 to 7 cm.) (*C. annuum* var. *intermedia*) . Type 11
    - Fruits long (above 7 cm.) (*C. annuum* var. *longa*)—
      - Fruits slightly purple before maturity, smooth . . . Type 12
      - Fruits not purple before maturity, rough surfaced . . Type 13
  - Fruits not circular in transverse section—
    - Fruits angular or irregular in transverse section (*C. annuum* var. *grossa*)—
      - Fruits orange yellow when ripe . . . . Type 14
      - Fruits red when ripe—
        - Fruits not purple before maturity—
          - Plants short . . . . Type 15
          - Plants tall . . . . Type 16
        - Fruits slightly purple before maturity . . . . Type 17
    - Fruits quadrate in transverse section (*C. annuum* var. *quadrata*)—
      - Fruits short in length—
        - Leaves light green, plants early . . . . . Type 18
        - Leaves dark green, plants intermediate in maturity . Type 19
      - Fruits medium in length . . . . Type 20
- Calyx embracing the base, circular in transverse section—
  - Fruits erect (*C. annuum* var. *acuminata erecta*)—
    - Fruit orange . . . . Type 21
    - Fruit red . . . . Type 22
  - Fruits pendent (*C. annuum* var. *acuminata pendula*)—
    - Fruit orange—
      - Fruit short in length . . . . Type 23
      - Fruit medium in length—
        - Leaves light green, plants spreading . . . . Type 24
        - Leaves dark green, plants erect . . . . . Type 25
      - Fruit long—
        - Leaves very light green—
          - Plants early . . . . Type 26
          - Plants late . . . . Type 27
        - Leaves dark green—
          - Fruits not purple before maturity . . . Type 28
          - Fruits moderately purple before maturity . . Type 29
    - Fruits red—
      - Fruits short in length—
        - Leaves light green, plants spreading . . . . Type 30
        - Leaves green, plants tall . . . . Type 31
        - Leaves dark green
          - Plants spreading, early . . . . . . Type 32
          - Plants erect, tall, intermediate in maturity . . Type 33
      - Fruits medium in length—
        - Leaves light green, fruit moderately purple before maturity Type 34
        - Leaves green, fruit not purple before maturity . . Type 35
        - Leaves dark green, fruit with much purple colour before maturity—
          - Plants early, spreading . . . . . . Type 36
          - Plants late, erect . . . . Type 37
      - Fruits long—
        - Fruit not wrinkled—
          - Fruits not purple before maturity, leaves light green . . . . Type 38
          - Fruits moderately purple before maturity, leaves green . . . . Type 39

Fruits long—*contd.*
Fruits not wrinkled—*contd.*
Fruits with much purple colour before maturity—
Leaves green . . . . Type 40
Leaves dark green. . . . . . . Type 41
Fruits wrinkled—
Fruits not purple before maturity—
Leaves light green—
Plants very late . . . . . Type 42
Plants intermediate in maturity . . Type 43
Leaves green . . . . Type 44
Leaves dark green. . . . . . . Type 45
Fruits moderately purple before maturity—
Plants early . . . . . . Type 46
Plants intermediate in maturity . . . Type 47
Plants late in maturity . . . . . Type 48
Fruits with much purple colour before maturity—
Leaves light green . . . . . Type 49
Leaves green . . . . Type 50
Leaves dark green
Plants early . . . . Type 51
Plants late . . . . Type 52

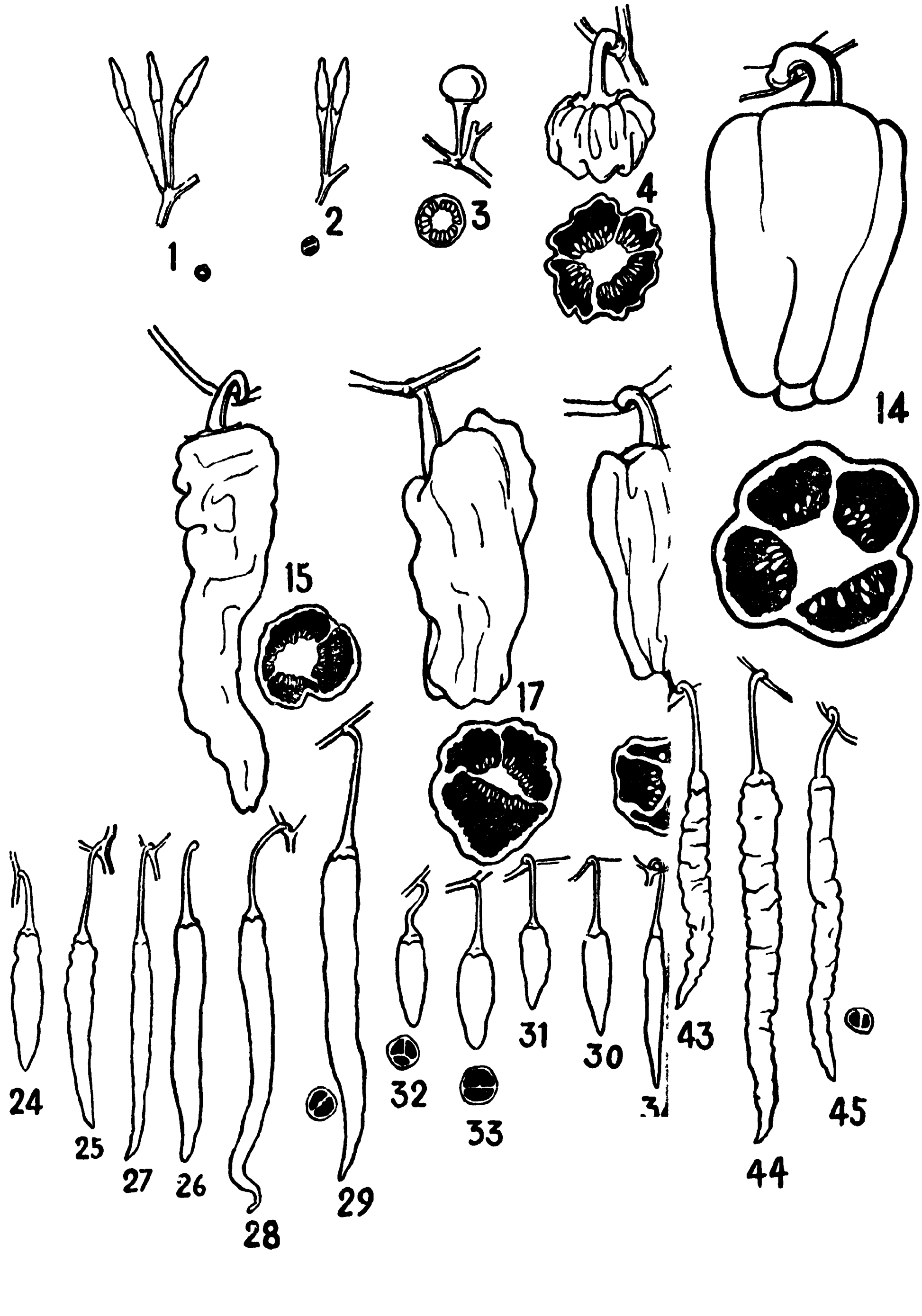
Statement showing the origin of the seed from which cultures were grown for the isolation of the types.

Place	District	Province	Type No. 1928-29.
Peshawar	Peshawar	N. W. Frontier	6
"	"	"	7
Lahore	Lahore	Punjab	32
Saharanpur	Saharanpur	U. P.	8
"	"	"	23
"	"	"	31
"	"	"	10
Pusa Farm	Darbhanga	Bihar and Orissa	3
"	"	"	4
"	"	"	13
"	"	"	41
Cuttack	Cuttack	"	22
"	"	"	46
Birbhum	Birbhum	Bengal	21
"	"	"	24
"	"	"	30

Statement showing the origin of the seed from which cultures were grown for the isolation of the types—contd.

Place	District	Province	Type No. 1928-29
Faridpur	Faridpur	Bengal	25
"	"	"	28
Jessore	Jessore	"	26
"	"	"	29
Berhampur	Berhampur	"	38
Howrah	Howrah	"	40
Comilla	Tipera	"	35
"	"	"	39
"	"	"	43
"	"	"	51
Sutton's Mammoth Long Red	....	....	15
Sutton's Colossal	....	....	14
Sutton's Spanish Giant	....	....	17
Jorhat	Sibsagar	Assam	34
Surma Valley	"	"	36
" "	"	"	37
Nadiad	Kaira	Bombay	44
	"	"	50
"	"	"	52
Ahmedabad	Ahmedabad	"	33
"	"	"	45
"	"	"	48
Bail Hongal	Belgaum	"	49
Gadag	Dharwar	"	42
"	"	"	47
Kumpta	Kanara	"	9
Malabar	Malabar	Madras	1

PLATE I.



Statement showing the origin of the seed from which cultures were grown for the isolation of the types—concld.

Place	District	Province	Type No. 1928-29
Malabar	Malabar	Madras	2
Coimbatore	Coimbatore	"	16
Ganjam	Ganjam	"	27
Meiktila	Meiktila	Burma	5
"	"	"	18
"	"	"	19
"	"	"	20
Allanmyo	Thayetmyo	"	11
"	"	"	12

IV. Description of the types.

The fruits of all types are illustrated on Plate I.

Type 1. Plants tall (76 cm.), very late, prolific, perennial ; leaf 12·0 cm. × 5·8 cm., green ; flowers 2 or more in the axil ; pedicel longer than the fruit ; corolla greenish white ; calyx enclosing the base of the fruit ; style white ; fruit short, 1·8 cm. × 0·3 cm., two celled, elongated, circular in transverse section, erect or sub-erect, unripe green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·12 gram. A very pungent form.

This type agrees with the species *C. frutescens* of Irish.

Type 2. Plants tall (73 cm.), late, prolific, perennial ; leaf 7·0 cm. × 4·2 cm., yellowish green ; flowers 2 or more in the axil ; pedicels longer than the fruit ; corolla greenish white ; calyx enclosing the base of the fruit ; style white, fruit short, 1·8 cm. × 0·3 cm., two celled, elongated, circular in transverse section, erect or sub-erect, unripe white without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·12 gram. A very pungent form.

This type agrees with the *C. frutescens* of Irish.

Type 3. Plants tall (66·0 cm.), intermediate in maturity, poor in bearing, annual ; leaf 8·5 cm. × 4·2 cm., purple ; flower one in the axil ; pedicel nearly equal to the fruit ; corolla purple ; calyx not enclosing the base of the fruit ; style purple ; stigma purple ; fruit short, globular, 1·2 cm. × 1·4 cm., 3 celled, circular in transverse section, erect, unripe purple becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit 0·98 gram (see Plate III).

This type does not agree exactly with any of the types described by Irish; it shows, however, similarity with the form "Black Nubian" (Irish page 76).

Type 4. Plants tall (72 cm.), intermediate in maturity, moderate in bearing, annual; leaf 9·6 cm.×5·2 cm., dark green; flower one in the axil; pedicel nearly equal to the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, swollen, completely corrugated, broader than long, globular, 3·0 cm.×4·0 cm., 3 to 4 celled, irregular in transverse section, pendent, unripe green with much purple colour, becoming red when mature, apex blunt, very broad, flesh thick, average weight of a fresh ripe fruit 5·6 grams (see Plate IV).

This type resembles the form Squash (Irish, page 87).

Type 5. Plants tall (61 cm.), intermediate in maturity, prolific, annual; leaf 9·1 cm.×4·8 cm., dark green; flower one in the axil; pedicel nearly equal to the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 2·4 cm.×2·8 cm., 3 celled, globular, irregular in transverse section, corrugated at base, broader than long, pendent, unripe dark green without any purple colour, becoming red when mature, apex blunt with distinct depression at the base of style, flesh thick, average weight of a fresh ripe fruit 5·3 grams.

This type is not described by Irish.

Type 6. Plants medium in height (57 cm.), early, moderate in bearing, annual; leaf 12·0 cm.×5·2 cm., light green; flower one in the axil; pedicel nearly equal to the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 2·0 cm.×1·8 cm., 3 celled, symmetrically globular, circular in transverse section, not corrugated, hard, pendent, unripe light green with moderate purple colour, becoming red when mature, apex blunt, flesh rather thick, average weight of a fresh ripe fruit 2·3 grams.

This type resembles the form Cherry described by Irish (page 93).

Type 7. Plants medium in height (47 cm.), early, moderate in bearing, annual; leaf 8·5 cm.×3·5 cm., green; flower one in the axil; pedicel nearly equal to the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 1·7 cm.×1·9 cm., 3 celled, symmetrically globular, circular in transverse section, not corrugated, pendent, unripe light green with slight purple colour, becoming red when mature, apex blunt, flesh rather thick, average weight of a fresh ripe fruit 2·6 grams.

This type resembles the form Cherry (Irish, page 93).

Type 8. Plants tall (62 cm.), early, moderate in bearing, annual; leaf 8·5 cm. ×4·1 cm., light green; flower one in the axil; pedicel nearly equal to the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 1·5 cm.×1·1 cm., 2 to 3 celled, globular, with distinct apical point, circular in transverse section, erect, unripe light green with much purple colour, orange when mature, flesh thin, average weight of a fresh ripe fruit 0·74 gram (see Plate II).

This type was isolated from a culture which was splitting into forms with red and yellow and erect and pendent fruits.

It may resemble the form Prince of Wales described by Irish (page 93); it is not however stated by Irish whether this form has erect fruits.

Type 9. Plants medium in height (46 cm.), early, moderate in bearing, annual; leaf 9 5 cm.×4·5 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 3·5 cm.×1·7 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with moderate purple colour, becoming red when mature, apex acute, flesh thick, average weight of a fresh ripe fruit 2·6 grams.

This type is not described by Irish.

Type 10. Plants medium in height (58 cm.), intermediate in maturity, moderate in bearing, annual; leaf 8·5 cm.×4·5 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 3·7 cm.×1·7 cm., 2 to 3 celled, elongated, circular in transverse section, pendent, unripe green with a slight purple colour, becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit 3·1 grams.

This type is not described by Irish.

Type 11. Plants tall (70·0 cm.), intermediate in maturity, poor in bearing, annual; leaf 8·0 cm.×3·9 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit medium in length, 1·2 cm.×2·4 cm., 2 celled, elongated, more or less conical, circular in transverse section, pendent, unripe dark green without any purple colour, becoming red when mature, apex acute, flesh thick, average weight of a fresh ripe fruit 4·6 grams.

This type is not described by Irish.

Type 12. Plants tall (62·0 cm.), early, prolific, annual; leaf 8·0 cm.×3·5 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 7·5 cm.×1·6 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with a slight purple colour, becoming red when mature, apex acute, flesh thick, surface smooth, average weight of a fresh ripe fruit 4·1 grams.

This type is not described by Irish. It was isolated from a culture which was splitting as regards the size of its fruits.

Type 13. Plants medium in height (57·0 cm.), early, moderate in bearing, annual; leaf 9·1 cm.×4·1 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 13·0 cm.×2·2 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green without any purple colour, becoming red when mature, apex acute, flesh thick, surface rough, average weight of a fresh ripe fruit 7·5 grams.

This type resembles the form Cardinal (Irish, page 78).

Type 14. Plants medium in height (50·0 cm.), very late, very poor in bearing, annual; leaf 10·5 cm.×5·0 cm., green; flower one in the axil; pedicel shorter than

the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 10·0 cm.×7·0 cm., 4 celled, elongated, angular in transverse section, pendent, unripe dark green with no purple colour, becoming orange yellow when mature, apex blunt and lobed, flesh thick, average weight of a fresh ripe fruit 37 grams.

This culture was obtained from Messrs. Sutton and Sons (Calcutta) under the name of Colossal and according to their catalogue[1] has red fruits. The type as isolated by us, however, has orange yellow fruits and resembles the form Yellow Spanish of Irish.

Type 15. Plants short (37·0 cm.), intermediate in maturity, poor in bearing, annual; leaf 9·2 cm.×5·1 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 13·5 cm.×3·5 cm., 3 celled, elongated, circular in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex acute, sometimes lobed, flesh thick, average weight of a fresh ripe fruit 19·0 grams.

This type was received from Messrs. Sutton & Sons (Calcutta), with the name Mammoth Long Red. It resembles the form Elephant's Trunk described by Irish (page 80).

Type 16. Plants very tall (78·0 cm.), very late, very poor in bearing, annual; leaf 7·4 cm.× 1·1 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit medium in length, 6·0 cm.×2·5 cm., 2-3 celled, elongated, angular in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex blunt and lobed, flesh thick, average weight of a fresh ripe fruit 3·6 grams.

This type resembles the form Sweet Spanish of Irish (page 83-4).

Type 17. Plants tall (72·0 cm.), late, very poor in bearing, annual; leaf 8·0 cm.×3·8 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 10·3 cm.× 5·0 cm., 3-4 celled, elongated, angular in transverse section, pendent, unripe dark green with a slight purple colour, becoming red when mature, apex blunt and lobed, flesh thick, average weight of a fresh ripe fruit 67 grams (see Plate V).

This culture was received from Messrs. Sutton & Sons (Calcutta), with the name Spanish Giant. It resembles the form Sweet Spanish of Irish (page 83—4).

Type 18. Plants tall (62·0 cm.), early, prolific, annual; leaf 9·0 cm.× 4·6 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short 4·0 cm.×3·0 cm., 3 celled, elongated, quadrate in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit 11·4 grams.

This type is not described by Irish.

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[1] Sutton's Garden Seeds, 1927.

Type 19. Plants medium in height (60·0 cm.), intermediate in maturity, prolific, annual; leaf 8·5 cm. × 4·6 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 3·9 cm. × 3·0 cm., 3 celled, elongated, quadrate in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit, 7·9 grams.

This type is not described by Irish.

Type 20. Plants tall (70·0 cm.), early, moderate in bearing, annual; leaf 7·5 cm. × 3·5 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit medium in length, 4·8 cm. × 2·6 cm., 2-3 celled, elongated, somewhat conical in shape, quadrate in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex acute, flesh thick, average weight of a fresh ripe fruit 6·0 grams.

This type is not described by Irish.

Type 21. Plants medium in height (57·0 cm.), late, moderate in bearing, annual; leaf 7·0 cm. × 3·0 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit short, 4·0 cm. × 0·7 cm., 2 celled, elongated, circular in transverse section, erect, unripe light green with much purple colour becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·93 grams.

This type resembles the Yellow Chilli of Irish (page 71).

Type 22. Plants very tall (80·0 cm.), early, prolific, annual; leaf 13·0 cm. × 6·0 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white, ; fruit medium in length, 6·4 cm. × 1·0 cm., elongated, circular in transverse section, erect, unripe dark green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·85 grams.

This type resembles the Chilli of Irish (page 70).

Type 23. Plants short (34·0 cm.), very early, moderate in bearing, annual; leaf 5·6 cm. × 3·0 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx almost enclosing the base of the fruit; style white; fruit short, 2·7 cm. × 1·2 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green with slight purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·87 grams.

This type resembles the Yellow Nepal of Irish (page 73).

Type 24. Plants spreading, tall (63·0 cm.), very early, prolific, annual; leaf 10·5 cm. × 5·0 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit medium in length, 5·0 cm. × 1·2 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with much purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·4 grams.

This type is not described by Irish.

Type 25. Plants erect, very tall (73·0 cm.), early, prolific, annual; leaf 10·0 cm.×5·0 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit medium in length, 7·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with moderate purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·7 grams.

This type is not described by Irish.

Type 26. Plants medium in height (54·0 cm.), early, prolific, annual; leaf 9·5 cm.× 4·2 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx almost enclosing the base of the fruit; style purple; fruit long, 8·4 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green with much purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 4·0 grams.

This type is not described by Irish.

Type 27. Plants medium in height (51·0 cm.), late, prolific, annual; leaf 8·8 cm.×3·8 cm., light green, flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 8·2 cm. ×0·7 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with much purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·8 grams.

Type 28. Plants medium in height (53·0 cm.), early, prolific, annual; leaf 9·0 cm.×3·7 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 10·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green without any purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·8 grams.

Type 29. Plants very tall (83·0 cm.), late, prolific, annual; leaf 13·0 cm.×6·0 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style purple; fruit long, 12·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green with moderate purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 5·5 grams (see Plate II).

This type and the two preceding types, 27 and 28, resemble the Long Yellow Cayenne of Irish (page 72-73).

Type 30. Plants spreading, medium in height (48·0 cm.), late, poor in bearing, annual; leaf 8·5 cm.×3·5 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit short, 4·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with much purple colour, becoming red when mature, apex blunt, flesh thin, average weight of a fresh ripe fruit 1·6 grams.

Type 31. Plants spreading, tall (69·0 cm.), early, moderate in bearing, annual: leaf 9·5 cm.×4·6 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit short, 3-0 cm.×1·1 cm., 2-3 celled, elongated, circular in transverse section, pendent, unripe light green with moderate purple colour becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·3 grams.

Type 32. Plants spreading, medium in height (49·0 cm.), early, moderate in bearing, annual; leaf 10·5 cm.×4·7 cm., dark green; flower one in the axil: pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit short, 3·3 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·4 grams.

Type 33. Plants erect, medium in height (60·0 cm.), intermediate in maturity, prolific, annual; leaf 10·3 cm.×4·9 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx almost enclosing the base of the fruit; style purple; fruit short, 3·5 cm.×1·2 cm., 2 celled, elongated, circular in transverse section, pendent, unripe dark green with much purple colour, becoming red when mature, apex acute, flesh rather thick, average weight of a fresh ripe fruit 2·2 grams.

This type and types 30, 31, 32, resemble the Nepal Chilli of Irish (page 73).

Type 34. Plants tall (63·0 cm.), very early, very prolific, annual; leaf 10·6 cm.×4·6 cm., light green; flower one in the axil: pedicel shorter than the fruit: corolla white; calyx enclosing the base of the fruit; style purple; fruit medium in length, 5·7 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with moderate purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·1 grams.

Type 35. Plants medium in height (57·0 cm.), early, moderate in bearing, annual; leaf 7·5 cm.×1·2 cm., green: flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit medium in length, 6·2 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex acute flesh thin, average weight of a fresh ripe fruit 1·9 grams.

Type 36. Plants spreading, medium in height (52·0 cm.), early, prolific, annual; leaf 9·5 cm.×4·6 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style purple; fruit medium in length, 5·6 cm.×1·3 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·4 grams.

Type 37. Plants erect, medium in height (50·0 cm.), late, poor in bearing, annual; leaf 7·0 cm.×2·8 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style purple; fruit medium in length, 5·7 cm.×0·8 cm., 2 celled, elongated, circular in transverse

section, pendent, unripe dark green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·6 grams.

This type and types 34, 35, 36 do not appear to be described by Irish.

Type 38. Plants medium in height (60·0 cm.), late, prolific, annual; leaf 9·8 cm. × 4·3 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 10·8 cm. × 0·8 cm., 2 celled, elongated, circular in transverse section, not wrinkled, pendent, unripe light green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·5 grams.

Type 39. Plants tall (68·0 cm.), late, prolific, annual; leaf 10·0 cm. × 4·5 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 8·3 cm. × 1·1 cm., 2 celled, elongated, circular in transverse section, not wrinkled, pendent, unripe light green with slight purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 3·9 grams (see Plate III).

Type 40. Plants medium in height (55·0 cm.), intermediate in maturity, moderate in bearing, annual; leaf 9·0 cm. × 3·8 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 7·8 cm. × 0·8 cm., 2 celled, elongated, circular in transverse section, not wrinkled, pendent, unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·0 grams.

Type 41. Plants tall (61·0 cm.), early, very prolific, annual; leaf 12·5 cm. × 5·2 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white, calyx enclosing the base of the fruit; style white; fruit long, 9·4 cm. × 1·1 cm., 2 celled, elongated, circular in transverse section, not wrinkled, pendent, unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 5·0 grams.

This type and types 38, 39, 40 resemble the long Cayenne of Irish (page 71).

Type 42. Plants medium in height (51·0 cm.), very late, poor in bearing, annual, leaf 7·0 cm. × 2·8 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 13·0 cm. × 0·7 cm., 2-3 celled, elongated, circular in transverse section, wrinkled, pendent, unripe light green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·3 grams.

Type 43. Plants medium in height (41·0 cm.), intermediate in maturity, poor in bearing, annual; leaf 10·1 cm. × 5·1 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 8·2 cm. × 1·1 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·4 grams.

Type 44. Plants medium in height (50·0 cm.), very late, poor in bearing, annual; leaf 11·0 cm.×5·5 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 13·3 cm.×1·2 cm., 3 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 4·2 grams.

Type 45. Plants medium in height (60·0 cm.), intermediate in maturity, very prolific, annual; leaf 10·9 cm.×4·3 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 10·5 cm.×1·0 cm., 2 celled, elongated, circular in transverse section wrinkled, pendent, unripe light green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 4·5 grams.

Type 46. Plants medium in height (52·0 cm.), early, prolific, annual; leaf 12·5 cm.×4·8 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla, white; calyx enclosing the base of the fruit; style white; fruit long, 8·9 cm.×1·1 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe fruit green with moderate purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·6 grams.

Type 47. Plants medium in height (60·0 cm.), intermediate in maturity, moderate in bearing, annual; leaf 8·0 cm.×3·5 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 13·5 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green with moderate purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 3·1 grams.

Type 48. Plants tall (68·0 cm.), late, very prolific, annual; leaf 11·9 cm. ×6·1 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 13·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green with moderate purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 5·1 grams.

Type 49. Plants medium in height (57·0 cm.), very late, poor in bearing, annual; leaf 9·8 cm.×4·2 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 10·5 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·1 grams.

Type 50. Plants medium in height (57·0 cm.), late, moderate in bearing, annual; leaf 11·0 cm.×5·0 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 9·0 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent,

unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·2 grams.

Type 51. Plants tall (67·0 cm.), early, very prolific, annual; leaf 11·3 cm.×5·5 cm., dark green; flower one in the axil: pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 8·2 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe light green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 3·9 grams.

Type 52. Plants tall (66·0 cm.), very late, prolific, annual; leaf 13·5 cm. ×6·2 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 12·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe light green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 3·8 grams.

This type and types 42 to 51, are not described by Irish.

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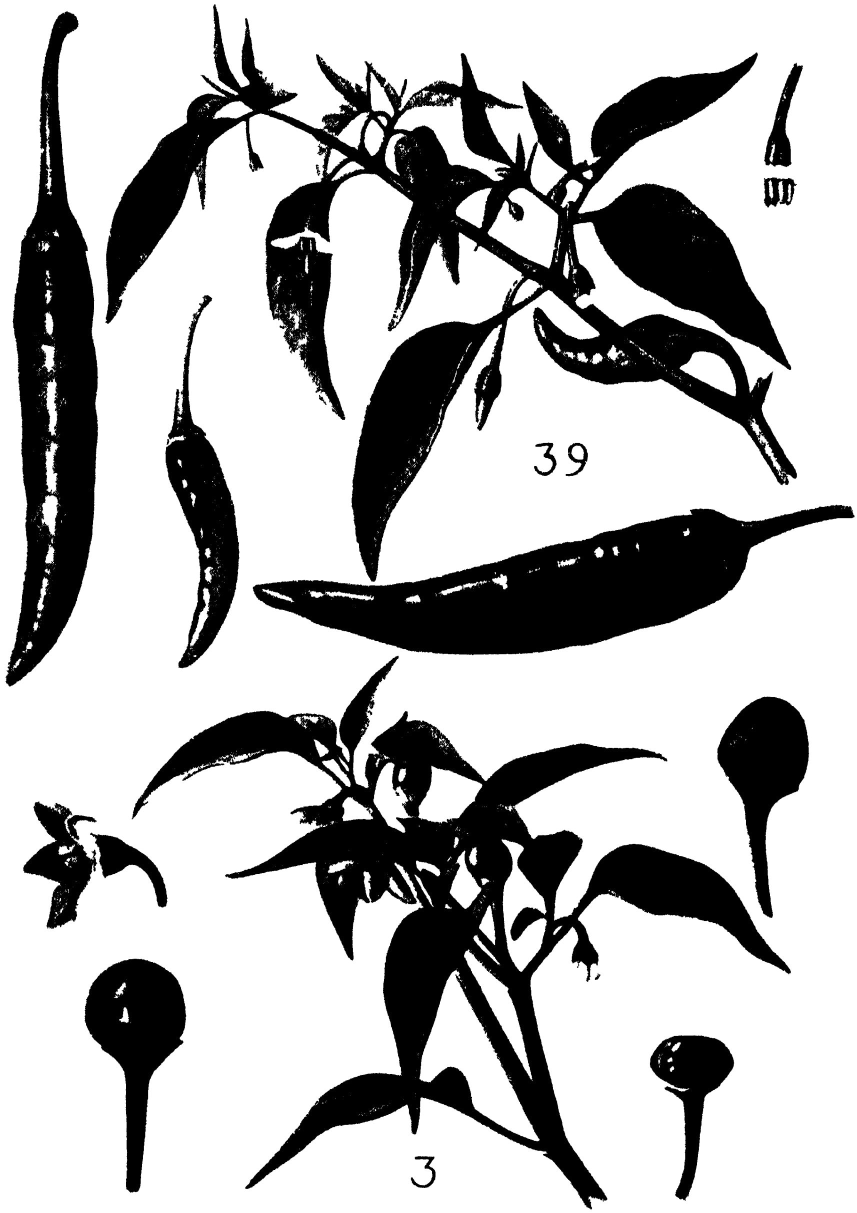
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Memoirs of the Department of Agriculture in India

Studies in Indian Pulses

I. Lentil (*Ervum lens*, Linn.)

BY

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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CONTENTS

STUDIES IN INDIAN PULSES.

1. Lentil (*Ervum lens*, Linn.)

BY

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(Received for publication on 31st July 1928.)

I. Introduction.

Although the lentil is recognised as a valuable pulse grown as a winter crop all over India, little attention has hitherto been paid to this plant. It is known to be the most nutritious of the pulses and is an important item in the diet of some people particularly those of Eastern Bengal.

It is not one of those crops of which separate statistical records are kept, and hence it is difficult to estimate the correct yield and area. It is cultivated, however, in all parts of India either as a separate or as a mixed crop, and its economic importance justifies a careful study of the plant.

According to De Candolle[1] "........... The lentil appears to have existed in Western temperate Asia, in Greece and in Italy, where its cultivation was first undertaken in very early pre-historic time, when it was introduced into Egypt. Its cultivation appears to have been extended at a less remote epoch, but still hardly in historic time, both east and west, that is into Europe and India. ...." "Adolphi Picket quotes a Persian name, '*mangu*' or '*margu*,' but he does not say whether it is an ancient name existing, for instance, in the Zend Avesta. He admits several Sanskrit names for the lentil, *masura*, *renuka*, *mangalya*, etc., while Anglo-Indian botanists, Roxburgh and Piddington, knew none. As these authors mention an analogous name in Hindustani and Bengali, *mussour*, we may suppose that *massour* signifies lentil, while *Mangu* in Persian recalls the other name *mangalya*. As Roxburgh and Piddington give no names in other Indian languages, it may be supposed that the lentil was not known in this country before the invasion of the Sanskrit speaking race. As an article of food, it has been known from the most ancient times." In India the lentil is eaten as *dal*, flavoured with various aromatics and condiments, also as a component part of the dish called *khichri*. The young pod

[1] De Candolle, *Origin of Cultivated Plants*, 1904, p. 321.

is also eaten as a vegetable, and the dry leaves and stalks are greatly prized as fodder. In Europe this pulse meal, mixed with barley flour or other cereal and common salt, is sold as an invalid food under the name Ervalenta or Revalanta.[1]

The following chemical analysis is given by Leather [2] :—

	Per cent.
Moisture	8·03
Oil	1·06
Albuminoids	23·00
Soluble carbohydrates	61·14
Woody fibre	2·42
Soluble mineral matter	3·54
Sand and silica	0·81
Total nitrogen	3·94
Albuminoid nitrogen	3·68

Although it is cultivated to some extent outside India, the only references of any importance available regarding its cultivation are in the American literature. No attempt appears to have been made anywhere to isolate and describe the elementary species of which the crop is composed. Fruwirth [3] has attempted to separate lentil types according to the seed colour and has given a good description of the flower and the method of pollination.

A case of parallel variation in vetches and lentils is described by Vavilov.[4] Vetch (*Vicia sativa* Linn.) is often found as a weed in lentils and certain varieties of vetch are so similar to lentils in shape, colour and size of seed that they cannot be separated in sorting. These vetches also often flower and fruit at the same time as lentils and are, in fact, perfect "mimics" of the lentils. The whole series of varieties in these two genera show clearly that it is difficult even for an expert to separate several varieties of lentils and vetches by their seeds alone and, moreover, in the colour of their flowers and in many other characters lentils show a similar series of variations to vetches. Selection in lentil seed has, therefore, led to the rejection of all vetches except those which were closely similar to the lentil type; these vetches will persist as an impurity in lentils and can only be eliminated by raising pure line cultures of lentils.

Lentils—*Ervum lens*, Linn., *Lens esculanta* Moench., *Cicer lens*, Willd., *masur, channangi, mohr, chanching, kerze, adah, misurpurpur, misur-pappu*, etc.—belongs to the natural order *Leguminosae*, sub-order *Papilionaceae*, tribe *Viceae*, and is a small softly pubescent herb. The genus contains only one species and no references to the varieties and unit types of which this crop is composed can be traced. The existence of more than one variety of this species has been recognised by the Director of Land Records and Agriculture, Bengal [5] who reported the occurrence of two varieties of *Ervum lens* grown in Dacca; one was the Patna variety, and the other was found in Lower Bengal. The plants of the latter were said to be bushy

[1] Watt. *The Commercial Products of India*, 1908, p. 709.
[2] Indian Food Grains and Fodders. *Agri. Ledg.*, 1901, No. 10, p. 366.
[3] Fruwirth. *Die Zuchtung der landwirtschaftlichen kulturpflanzen* 3, 1901, 146-148.
[4] Vavilov, N. I. The law of homologous series in variation. *Jour. Genetics*, 12, 1912, 47-89.
[5] Watt. *The Commer. Prod. of India*, 1908, p. 709.

and to give a better outturn. G. L. C. Howard and Abdur Rahman Khan [1] also mention that large seeded types of lentil generally belong to the black cotton soil areas, whereas in Bihar the corresponding varieties have very small seeds.

Our detailed study of this crop shows that the Indian lentil crop, like most other Indian field crops, is not uniform but consists of many different forms, distinguished from one another by various morphological and physiological characters.

A collection of mixed bazar samples was made in 1924 from the undermentioned localities and isolation of pure types was continued in the following years. All cultures, as usual, were started from bagged seed of a single plant, and 66 pure types were obtained, some of which show great agricultural promise.

TABLE I.

Locality from which original samples of lentils were obtained and types isolated from them.

Province	Locality	Types isolated at Pusa
Burma	Allanmyo	T. 57.
	Sagaing	T. 56.
Bengal	Birbhum	T. 31 and T. 13.
	Burdwan	T. 7.
	Jessore	T. 55 and T. 66.
	Khulna	T. 6 and T. 17.
	Murshidabad	T. 26 and T. 45.
	Pabna	T. 16 and T. 63.
	Rajshahi	*Nil.*
Bihar and Orissa	Arrah	T. 22.
	Darbhanga	*Nil.*
	Patna	T. 19.
	Gaya	T. 13, 15, 39 and 59.
	Muzaffarpur	*Nil.*
	Sabour	T. 27 and T. 29.
	Sepaya	T. 32.
	Cuttack	T. 44.

[1] Howard, G. L. C., and Abdur Rahman Khan. Studies in Indian Oil Seeds, No. 2. Linseed. *Mem. Dept. of Agri. India, Bot. Ser.*, XII, 4, 1924, p. 183.

TABLE I *contd.*

Locality from which original samples of lentils were obtained and types isolated from them contd.

Province	Locality	Types isolated at Pusa
United Provinces of Agra and Oudh . . .	Agra . . .	T. 9.
	Aligarh . . .	T. 18.
	Bulandshahr . .	*Nil.*
	Gorakhpur . .	T. 11 and T. 23.
	Lucknow . .	T. 34 and T. 50.
	Muttra . . .	T. 2 and T. 30.
	Muzaffarnagar .	T. 35 and T. 52.
	Partabgarh . .	T. 16 and T. 48.
Punjab	Amballa . .	T. 28.
	Ferozepur . .	T. 38.
	Gurdaspur . .	T. 36 and T. 51.
	Karnal . . .	*Nil.*
	Lahore . . .	*Nil.*
	Lyallpur . .	T. 40 and T. 58.
	Rohtak . . .	T. 65.
N. W. F. Province	Peshawar . .	T. 53.
Central Provinces	Jubbulpur and neighbourhood.	T. 3, 8, 12, 14, 19, 33, 41, 62 and 64.
Madras	Madras . . .	*Nil.*
	Coimbatore . .	*Nil.*
Bombay	Bailhongal . .	T. 25 and 61.
	Mirpurkhas . .	*Nil.*
	Poona . . .	T. 4 and 54.
	Sholapur . .	T. 5.
	Surat . . .	T. 1, 17, 37, 42 and 60.
	Wardha. . .	T. 10 and 24.

Cultivation. Watt [1] states that the lentil is cultivated in all parts of India especially in Bengal, Madras, Central Provinces and the United Provinces of Agra and Oudh. It is sown in all kinds of soils, but chiefly in low-lying land. In Bengal it thrives best on a clay soil, since in light soils the plants wither away. In rotation following paddy, the land receives three or four ploughings and the seed is sown from October to December. Sometimes it is sown mixed with barley. In Assam the crop is reported to prefer a light, loamy soil and an open situation, and generally follows a broadcasted rice crop, and is sown in mixture with mustard. In the United Provinces [2] the cultivation is most extensive in the damper regions and it is sown in all kinds of soil, but chiefly in low-lying land. In the Central Provinces and Berar it is generally sown on the best black soil. In the Punjab it is a *sailaba* or inundation crop, and new alluvial soils or light lands, not good enough for wheat, are selected, while in Bombay it is given a mixed black soil of moderate depth.

Yield. The average yield of this crop is from 8 to 12 maunds per acre and although no definite work is recorded on the selection and isolation of pure types, Church [3] has stated that the yield of lentil may be increased by the selection of seed for sowing, since there are some varieties of lentil, which produce seed weighing twice as much as the small common sort.

The following Table shows the approximate yield of seed in 1928, in tolas (1 lb. =40 tolas), obtained from 20 plants of each of the 66 types of lentils isolated in the Botanical Section.

TABLE II.

Showing the approximate weight of seed taken from 20 plants selected at random from each type.

Size of seed	Type No.	Weight in tolas	Size of seed	Type No.	Weight in tolas	Size of seed	Type No.	Weight in tolas
Large .	41	5	Intermediate	42	6	Small .	39	20
	30	7		50	7		56	22
	16	11		37	8		6	27
	13	12		64	9		57	28
	5	13		12	10		66	29
	17	14		1	10		55	30
	14	14		24	11		58	105
	60	15		48	14		40	138
	8	16		21	14		28	245
	29	16		31	15			
	59	17		25	15			
	13	18		54	16			
	15	19		4	19			
	3	20		61	19			

[1] Watt. *Commercial Products of India*, 1910, p. 708.
[2] Duthie and Fuller. *Field and Garden Crops*, Pt. II, p. 13.
[3] Church, A. H. *Food*, 1882.

TABLE II—*contd.*

Showing the approximate weight of seed taken from 20 plants selected at random from each type—contd.

Size of seed	Type No.	Weight in tolas	Size of seed	Type No.	Weight in tolas	Size of seed	Type No.	Weight in tolas
Large .	9	71	Intermediate	62	25	Small .		
	20	80		7	25			
	2	102		32	26			
	10	105		26	26			
	19	145		43	27			
				47	28			
				45	29			
				44	30			
				63	30			
				46	36			
				53	50			
				22	106			
				49	125			
				52	135			
				65	145			
				36	150			
				23	150			
				51	150			
				33	150			
				35	190			
				38	195			
				11	195			
				27	205			
				31	225			

From the above Table, it is apparent that there is great diversity in the relative yielding capacity of the different types in all the large, intermediate and the small-seeded varieties, and that from an economic point of view it will be advantageous to conduct varietal trials for yield with types 2, 10 and 19 of the large seeded variety, types 11, 27 and 34 of the intermediate and types 28 and 40 of the small-seeded variety.

All the types which have originated from samples obtained from Burma and Bengal have white flowers and have small or intermedi e-sized seed. Two types from Bailhongal and one from Jubbulpur also have white flowers and intermediate-sized seed. None of the large or bold seeded varieties have pure white flowers and the majority of these types have come from Peninsular India. Almost all the heavy yielding varieties, whether small, intermediate or bold seeded, have coloured flowers.

II. GENERAL BIOLOGY.

1. Root System.

The wide range in the soil and agricultural conditions in the localities from which the various mixed samples were drawn suggested that a study of the root systems

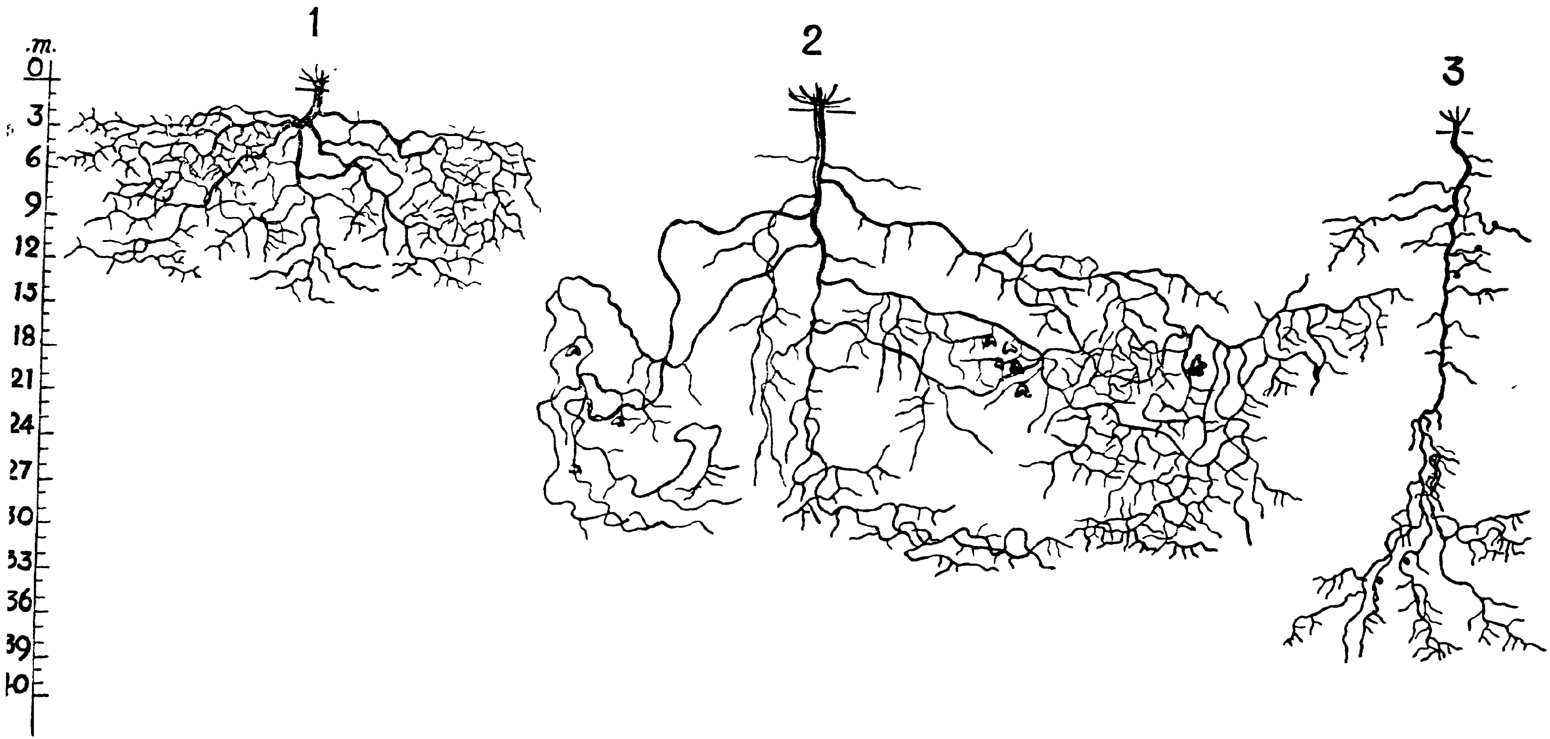


Fig. 1. Root system in lentils. 1. Shallow 2. Intermediate 3 Deep.

of some types might prove useful. It was interesting to find that the results of such a study confirmed the observations of workers on some other crops such as Linseed and *Khesari* (*Lathyrus sativa*, L.). Three types of root systems were recognised:

(1) Almost all the types which originated from samples obtained from the black cotton soil areas had a deep root system. Such root systems are often characteristic of crops growing in tracts where the soil surface cracks and rapidly dries and where the crop is dependent mainly on the moisture of the lower layers.

(2) Types obtained from the alluvium showed a well branched shallow root system and abundant healthy root nodules.

(3) Types selected from the Punjab and N. W. F. Province generally showed an intermediate condition.

The deep rooted systems seem to be associated with bold seed and a somewhat sparse branching which results in a low yield, while types with shallow root systems generally have intermediate or small seed, a profuse branching and consequently a comparatively high yield. These facts agree closely with similar observations on linseed and *khesari* [1] and furnish additional evidence of the importance of the root system in selecting unit species of a crop to suit different soil conditions.

In 1926 the lentil crop was very badly affected by Aphids at Pusa, and a close examination showed that the infection varied with the type of the root system the deep rooted varieties coming from Peninsular India being affected the most and the alluvial types the least. The same phenomenon has been recorded in the case of *khesari* and illustrates how a physiological derangement occasioned by a root system not being adapted to the soil conditions may cause an increased susceptibility to pests and diseases. In the case of the attack of aphids on lentils, the pest was defeated by releasing on the lentil plants a number of lady bird beetles which are the natural enemies of aphids.[2]

2. *Flowering.*

The flowers are borne singly or in 1, 2, 3, or rarely 4 flowered racemes on short peduncles, which are about as long as the leaves and extend some distance beyond the flowers. The lowermost buds open first and it takes nearly a fortnight for the complete opening of all the flowers on a single branch.

A study of the time of opening of flowers in lentils showed that this phenomenon depended chiefly on the temperature and humidity and is more or less the same in all the types. A number of buds which were likely to open on the next day, were labelled in the evening and observations were made at regular intervals on the next and the following mornings until dusk. In the majority of cases it was found that on a clear day the flowers begin to open at about 8 A.M., but mostly between 9 A.M.

[1] Howard, A. Crop Production in India, 1924, p. 51.

[2] Dutt, G. R. Aphids and Lady-bird Beetles. *Agri. Jour. of India*, XXII, 1927, 291-292.

and 10 A.M., and at times continue to do so till 12 noon. They remain open the whole of that night and the next day and some of them begin to close at or about 4 to 5 P.M., while others struggle on till the next morning. On the third day, however, all of them close completely and the corolla begins to fade. The pod makes its appearance 3 or 4 days later. On a cloudy day, however, the flowers do not open till midday and continue to do so till the evening (5 P.M.) remaining open the whole of the next day and beginning to close on the third day. Flowering begins from the lowest flower and proceeds up the stem.

3. *Pollination.*

The following description of the method of fertilization in lentil is given by Knuth [1] :—

" The bluish-white flowers of the species are marked with blue lines on the vexillum (nectar guides), and a small patch on the tip of the carina (pollen guide). Kirchner ('Flora v. Stuttgart,' p. 508) states that the vexillum, which but slightly ensheaths the other parts of the flower, comes into close contact with the alæ by means of two forwardly directed folds of a projecting ridge. The style bears projecting hairs only on its inner side. Otherwise the mechanism agrees with that of Vicia Ervilia. Kerner says that the flowers are fertile when insect visits are prevented.

Visitors. Herm. Muller saw the honey bee (Skg.) and a butterfly (Cœnonympha pamphilus). 'Weit. Beob.' II, p. 258."

Our observations here confirm this description and we have found that the anthers burst in the bud some time before the opening of the flower. An examination in the evening of 50 young buds which were likely to open the next morning showed this condition in the majority of cases. The different stages in the development of the bud are shown in Plate I.

Bees, small butterflies and numerous ants visit the flowers throughout the day. Seed is set freely under bags and no serious effects, excepting a slight elongation of the nodes and foliage in general, has been observed in plants under bags.

4. *Cross-fertilization.*

Self-fertilization seems to be the general rule with this crop and we have not yet come across any case of natural cross-fertilization. The fact that bees and other insects visit the lentil crop in abundance suggests the possibility that cross-fertilization may take place.

5. *Hybridization.*

Notwithstanding the fact that the flowers of lentils are very small no special trouble is met with in hybridizing different types. A number of crosses have been made to study the genetic relation of different combinations, such as bold × small

[1] Knuth. Handbook of Flower Pollination, Vol. II, p. 329.

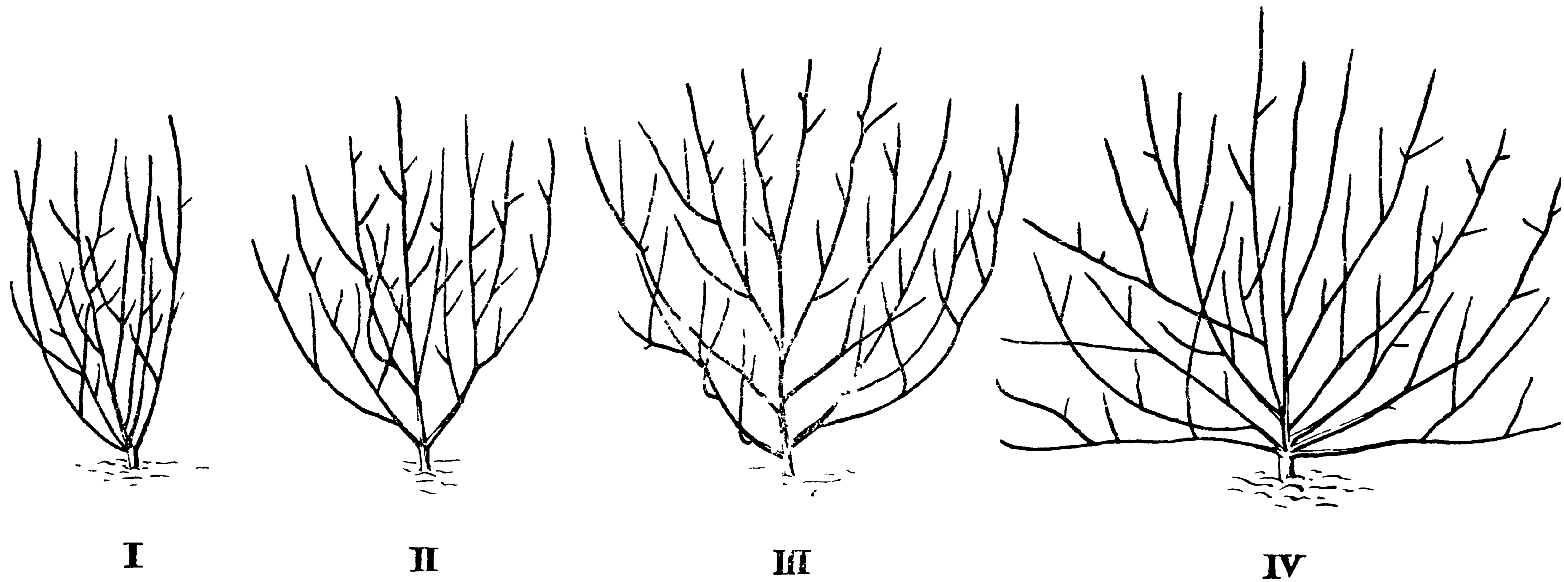


Fig 2. Showing different modes of branching.

seed, white × coloured flowers, self coloured × mottled seeds, etc., the results of which will be published later. Humidity, however, appears to be a limiting factor in the success of crossing, as hardly any setting takes place when the hybridized flowers are covered with ordinary manilla paper bags, while no difficulty is experienced when they are covered with small muslin bags which provide sufficient æration.

III. Classification and Description of the Types.

Sixty-six unit species of lentil have been isolated from the original mixed seed samples. The chief morphological characters in which these types differ are :—(1) Size, colour and markings of the seed ; (2) colour of the flower ; (3) time of flowering as measured by the opening of the first flower ; (4) habit ; (5) colour of the leaf ; and (6) colour of the stem.

Prain[1] describes this genus as follows :--

"218, LENS, Gren. & Godr. Annual herbs, erect or subscandant ; *leaves* usually even-pinnate, the rachis ending in a tendril or a simple point occasionally with a terminal leaflet ; stipules semisagittate, stipels 0. *Flowers* axillary, peduncled, solitary, or in few-flowered racemes ; bracts and bracteoles usually 0. *Sepals* connate in an oblique tube, lobes 5, elongate, subequal. *Petals* exserted, standard broad, narrowed to a very short, wide claw ; wings oblong, oblique, adnate in their middle to the shorter keel. *Stamens* 10, the vexillary one free, the others connate in an oblique sheath ; anthers uniform. *Ovary* subsessile, 2-ovuled ; style inflexed, bearded longitudinally on the inner face ; stigma terminal. *Fruit* a compressed 1-2 seeded pod, continuous within. *Seeds* compressed lenticular ; hilum ovate or oblong."

This description fits generally all the unit species described in this paper, but for the separation of the types, we must consider the characters in greater detail.

Habit. The general habit depends on three things the height, the mode of branching and the foliage. The height of the various unit species seems to be influenced by the environment and as it does not vary much in the different types it has not been taken as a differentiating character. The basal branches may be crowded giving an erect, more or less compact appearance (Fig. 2 -I) ; they may be semi-erect and somewhat open (Fig. 2-II) ; spreading and very much open (Fig. 2-III) ; or more or less trailing on the ground (Fig. 2-IV).

The nature of the branching is useful as a minor distinguishing character. The branching may be profuse or sparse. The size and form of the leaflets also influence the habit of the plant.

Maturity. The types show very great differences in the length of their growing period as well as in the time at which they start flowering. In 1927-28 the earliest type began to flower on the 4th December 1927 and the latest on the 18th February 1928 showing a very wide range indeed. The crop was sown on the 25th October

[1] Prain, D. *Bengal Plants*, Vol. I, 1903, p. 367.

1927. Types which started flowering from the 8th to the 10th week after sowing have been classified as very early; those which started from the 11th to the 13th week were considered to be early; those between the 14th and the 16th week were counted as medium in maturity; those between the 17th and 18th week were taken to be late, while those which flowered later than this were classified as very late (Table III).

TABLE III.

Maturity of different types as measured by the date of the first flower.

Very early	Early	Medium in maturity	Late	Very late
8th to 10th week after sowing	11th to 13th week after sowing	14th to 16th week after sowing	17th to 18th week after sowing	19th week or later after sowing
Types	Types	Types	Types	Types
2, 4, 5, 7, 8, 10, 13, 16, 17, 25, 29, 30, 31, 37, 39, 41, 43, 44, 45, 48, 54, 55, 56, 61, 64, 66.	1, 3, 6, 9, 11, 12, 14, 15, 18, 19, 20, 21, 22, 24, 26, 27. 32, 33, 42, 46, 47, 49, 50, 57, 58, 59, 60, 62, 63.	23, 28, 34, 35, 38, 51.	36, 52, 65	40, 53

Stem. The stem is usually much branched from the base, and is generally furrowed, angular, and hairy. It may be purely green or may have splashes of red colour at the base in addition.

Leaves. The types differ considerably both in the total length of the leaf, in the size and number of leaflets as well as in the tone of the colour of the foliage. The total length of the leaf has been used for describing the leaves as small (1·5 cm. to 2·1 cm.), medium (2·1 to 2·7 cm.), and large (2·7 cm. to 3·8 cm.). The average number of leaflets per leaf is also mentioned in the description of the types, and whenever the leaf has terminated in a small tendril a note to that effect has been made. In all other cases a tendril, which is nearly as long as the leaf is present. The leaflets are beset with fine hairs but there are no glandular knobbed hairs as are present in the case of gram. The foliage colour in the various types has been classified as yellowish green (T. 2); light yellowish green (T. 4); green (T. 44); dull green (T. 17); dark green (T. 7); and dark bluish green (T. 6). The shades of different colours observed in mass are shown in Plate II. These small coloured differences are best studied when the types are massed together and examined in the early morning or late evening light with the rays of the sun slanting and the sun behind the observer. At times a clear difference has also been observed at or about midday with the sun directly overhead.

Flowers. There is a very slight difference in the size of the flowers. The width of the standard ranges from 0·4 cm. to 0·5 cm. only, and hence this character has not been used for distinguishing types. The colour of the flower is a more important item and is described as :—

(1) *white*—when they are almost white with sometimes a suggestion of a slight trace of pink.
(2) *white with lilac colour on the veins of the standard only*, and a small blue patch on the tip of the carina.
(3) *pink.*
(4) *violet with a pinkish tinge.*
(5) *violet with a light pinkish tinge.*
(6) *violet.*
  (*a*) grade 1.
  (*b*) grade 2 (lighter than grade 1).

The important colour differences in the flower of lentil are shown in Plate III.

Kirchner[1] suggests that the blue lines on the vexillum (like those present in Flower class 2 above) are suggestive of nectar guides, and a small blue patch on the tip of the carina is probably the pollen guide.

The occurrence of 1, 2, 3, or rarely 4 flowers per peduncle was at first thought to furnish an important distinguishing character. But the variation from plant to plant in the same pure line culture was found to be so very great that this character was rejected in the classification. In different plants of the same pure line peduncles with 1, 2, or 3 flowers may be present in varying proportions (Table IV below), and although indications can generally be obtained which show whether the majority of peduncles in a particular type are 1, 2 or 3 flowered no definite and reliable conclusions can be based on this character.

TABLE IV.

Statement showing the number per plant of 1, 2 or 3 flowers on a peduncle in some lentil types.

Type	No. of flower-per peduncle												Total number of plants
	1	Nil	Nil	Nil	Very few	Very few	Very few	Few	Few	Few	Many	Many	
	2	Few	Many	Many	Many	Many	Many	Nil	Many	Many	Many	Few	
	3	Many	Few	Nil	Nil	Very few	Few	Many	Nil	Very few	Nil	Nil	
7		1	1	1	6	2	1	.	10	4		1	27
8		.	.	1	13	1	.	.	10			1	29
21		..	..	3	9	..	1		8	1			22
22		.	..	..	2	1	.		18		1	.	22
25		.	..		3	..	..	21		2	1	..	27

[1] Knuth. *Handbook of Flower Pollination*, Vol. II, p. 329.

Pods. These are rhomboid-oblong, smooth, compressed and tipped with the base of the style. They are described as bold, medium or small, according to their size, but these differences are not very appreciable and the character of the pod has not been used for distinguishing the types from one another.

Seed. This has furnished the most important character in the classification of the different types.

(1) *Size.* Three grades in the size of the seed have been distinguished and have been termed large, intermediate and small.

(2) *Ground colour.* This may be :—

(*a*) Prussian red (T. 1).
(*b*) Salmon buff (T. 2).
(*c*) Vinaceous buff (T. 3, 4, and 5).
(*d*) Vinaceous pink (T. 6).
(*e*) Buff pink (T. 7).
(*f*) Pale pinkish buff (All other types).

These colours are not very clear to the naked eye but can be made out when the seed is examined under the binocular. The higher the power of the lens, however, the lighter the tint appears, and hence all descriptions in the following pages are based upon the examination of the material with Zeiss Paired Eyepiece 4, and Objective 3, Magnification × 12, and when any comparison is to be made this magnification should be used. Ridgway's[1] colour book has been used for determining the various grades of ground colour.

(3) *Markings.* With the exception of a very few self coloured seed types, the majority have markings covering the whole of the ground colour, which therefore in some cases looks almost black to the naked eye, but examination with a lens shows clearly that the apparently uniform black colour is really due to the crowding together of a large number of dots or patches which for the sake of convenience have been distinguished into two kinds :

(*a*) Cloudy mottling which has more or less a continuous pattern made up of small dots, violet to ivory black in colour, between which minute areas of the ground colour can be seen with the aid of the lens. Three grades have been recognised—Grade 1 when the mottling is sparse; Grade 2, medium, when mottling is present uniformly, and Grade 3 when mottling is heavy.

(*b*) Sky-grey specklings which take the form of discontinuous spots much larger in size and unevenly distributed. Three grades of this too have been identified,- Grade 1 when the speckling is occasionally present and is rather sparse ; Grade 2 when the speckling is uniformly distributed and Grade 3 when the speckling is heavy.

Both cloudy mottling and sky-grey speckling occur simultaneously in all but a few types, and at times are intensified to such a degree that the entire seeds are coloured black or violet.

[1] Ridgway, R. *Colour Standards and Colour Nomenclature*, Washington.

(c) The hilum may be pale yellow without any markings or may be speckled at the micropylar end. At times this mark is very prominent (T. 41).

The ground colour and the markings described above are invariably always localised in the testa and do not extend to the cotyledons which generally have the usual characteristic pinkish yellow colour.

The seed colour in lentil does not show any correlation with the flower colour such as has been observed in *Pisum* and *Lathyrus sativus*. Thus in the peas the colourless testa is invariably associated with white flowers (with the exception of a few light-green seeded varieties),[1] while in *Khesari* [2] (*Lathyrus*) all the types with coloured flowers possess seed with mottling or marking on the seed coat. Plate IV shows the important colour patterns present on the seed of lentils. The seed is always compressed, smooth and lenticular, and when fully developed has nothing like the wrinkled forms found in peas and gram.

The amount of mottling or speckling and even the depth of the general colour vary with the age of the seed and indeed mottling and speckling are not fully developed until the seed is mature. Seed examination must therefore be done in mass and full weight must be given to possible differences in maturity. This probably explains the divergent results obtained by Fruwirth [3] in the experiments in which he attempted to separate types according to seed colour.

Our thanks are due to Mr. Sawan Mal Sikka, B.Sc. (Agr.), one of the post-graduate students in the Botanical Section, Pusa, for valuable help in this work, especially in colour determination of foliage, flowers and seed and their classification.

2. Key to the Types of *Ervum lens*, Linn.

I. Seeds Prussian Red.

- (A) Seeds not mottled.
  - *a*. Speckling occasional (grade 1).
    - 1. Hilum pale yellow.
      - (i) Seeds intermediate in size.
        - (1) Flowers pink . . . . Type 1.

II. Seeds Salmon Buff.

- (A) Seeds not mottled.
  - *a*. Speckling occasional (grade 1).
    - 1. Hilum speckled at the micropylar end.
      - (i) Seeds large.
        - (1) Flowers white with lilac colour on the veins only . Type 2.

[1] Wellensick, S. J. Genetic Monograph on Pisum—*Bibliographia Genetica*, II, 1925, 343-473.

[2] Howard, G. L. C., and Abdul Rahman Khan. The Indian Types of *Lathyrus sativus*, *Mem. Dept. of Agri. India, Bot. Ser.*, XV, 1928, No. 2.

[3] Fruwirth. *Die. Zuchtung der Landwirthschaftlichen Kultur (pflanzen,)* 3, 1910.

III. Seeds Vinaceous Buff.

(A) Seeds not mottled.

a. Speckling occasional (grade 1).

1. Hilum speckled at the micropylar end.

(i) Seeds large.

(1) Flowers white with lilac colour on the veins only . Type 3.

(ii) Seeds intermediate in size.

(1) Flowers white with lilac colour on the veins only . Type 4

(B) Mottling sparse (grade 1).

a. Speckling occasional (grade 1).

1. Hilum speckled at the micropylar end.

(i) Seeds large.

(1) Flowers white with lilac colour on the veins only . Type 5.

IV. Seeds Vinaceous pink.

(A) Mottling sparse (grade 1).

a. Speckling rare.

1. Hilum pale yellow.

(i) Seeds intermediate in size.

(1) Flowers white . . . . Type 6.

V. Seeds Buff pink.

(A) Mottling heavy (grade 3).

a. Speckling sparse (grade 1).

1. Hilum pale yellow.

(i) Seeds intermediate in size.

(1) Flowers white. . . . . Type 7.

VI. Seeds Pale pinkish Buff.

(A) Mottling heavy (grade 3).

a. Speckling sparse (grade 1).

1. Hilum pale yellow.

(i) Seeds large.

(1) Flowers violet with a pinkish tinge . . . . . Type 8.

(2) Flowers violet, grade 1 . . . . Type 9.

(3) Flowers violet, grade 2 . . . . Type 10.

(ii) Seeds intermediate in size.

(1) Flowers violet with a pinkish tinge . . . . Type 11.

(2) Flowers violet, grade 2 . . . . Type 12.

2. Hilum speckled at the micropylar end.

(i) Seeds large.

(1) Flowers with a pinkish tinge.

(*a*) Plants very early . . . . Type 13.

(*b*) Plants early

i. Semi-erect . . . . . . Type 14.

ii. Spreading . . . . . . Type 15.

(2) Flowers violet, grade 1.
(a) Plants very early.
i. Spreading.
(α) Leaves yellowish green . . . Type 16.
(β) Leaves dull-green . . . . Type 17.

(b) Plants early.
i. Semi-erect . . . . . . Type 18.
ii. Spreading . . . . . . Type 19.

(3) Flowers violet, grade 2.
(a) Plants early . . . . Type 20.

(ii) Seeds intermediate in size.
(1) Flowers violet with a pinkish tinge.
(a) Plants early.
i. Spreading.
(α) Leaves deep yellowish-green . . Type 21.
(β) Leaves green . . . . Type 22.

(2) Flowers violet, grade 1 . . . . . . Type 23.
(3) Flowers violet, grade 2 . . . . . . Type 24.

b_1 Speckling medium (grade 2)
1. Hilum pale yellow.
(i) Seeds intermediate in size.
(1) Flowers white
(a) Plants very early, leaves light-green . . . Type 25
(b) Plants early, leaves dark-green . . . . Type 26

(2) Flowers violet, grade 1 . . . . . . Type 27

(ii) Seed small.
(1) Flowers violet with a pinkish tinge . . . . Type 28.

Hilum speckled at the micropylar end.
(i) Seeds large.
(1) Flowers violet with a pinkish tinge . . . . Type 29.
(2) Flowers violet, grade 1. Type 30.

(ii) Seeds intermediate in size.
(1) Flowers white . . . . Type 31.
(2) Flowers violet with a pinkish tinge.
(a) Plants early.
i. Semi-erect . . . . . . Type 32.
ii. Spreading . . . . . . Type 33.

(3) Flowers violet, grade 1.
(a) Plants medium in maturity.
i. Spreading . . . . . . Type 34.
ii. Trailing . . . . Type 35.
(b) Plants late . . . . Type 36.

(4) Flowers violet, grade 2.
(a) Plants very early . . . . Type 37.
(b) Plants medium in maturity . . . . Type 38.

(iii) Seeds small.
- (1) Flowers violet with a pinkish tinge.
  - (*a*) Plants very early . . . . Type 39.
- (2) Flowers violet, grade 1.
  - (*a*) Plants very late . . . . Type 40.

c. Speckling heavy (grade 3).

1. Hilum speckled at the micropylar end.
   - (i) Seeds large.
     - (1) Flowers violet with a pinkish tinge . . . . Type 41.
   - (ii) Seeds intermediate in size.
     - (1) Flowers violet, grade 2 . . . . Type 42.

(B) Mottling medium (grade 2).

a. Speckling sparse (grade 1).

1. Hilum pale yellow.
   - (i) Seeds intermediate in size.
     - (1) Flowers white.
       - (*a*) Plants very early.
         - i. Semi-erect.
           - (α) Leaves dull green . . . . Type 43.
           - (β) Leaves green . . . . Type 44.
           - (γ) Leaves Dark-green . . . Type 45.
       - (*b*) Plants early.
         - i. Spreading . . . . Type 46.
         - ii. Trailing . . . . Type 47.
     - (2) Flowers violet with a pinkish tinge.
       - (*a*) Plants very early. . . . . . Type 48.
       - (*b*) Plants early.
         - i. Semi-erect.
           - (α) Leaves yellowish green . . . Type 49.
           - (β) Leaves Dull-green . . . . Type 50.
     - (3) Flowers violet, grade 1.
       - (*a*) Plants medium in maturity . . . . Type 51.
       - (*b*) Plants late . . . . Type 52.
     - (4) Flowers violet, grade 2.
       - (*a*) Plants very early.
         - i. Semi-erect.
           - (α) Leaves yellowish green . . . Type 53.
           - (β) Leaves light-green . . . Type 54
   - (ii) Seeds small.
     - (1) Flowers white.
       - (*a*) Plants very early.
         - i. Semi-erect . . . . Type 55.
         - ii. Spreading . . . . Type 56.
       - (*b*) Plants early . . . . Type 57.
     - (2) Flowers violet with a pinkish tinge. . . . . Type 58.

2. Hilum speckled at the micropylar end.
   - (i) Seeds large.
     - (1) Flowers violet, grade 1 . . . . Type 59.
     - (2) Flowers violet, grade 2 . . . . Type 60.
   - (ii) Seeds intermediate in size.
     - (1) Flowers white.
       - (a) Plants very early . . . . Type 61.
       - (b) Plants early.
         - i. Spreading . . . . Type 62
         - ii. Trailing . . . . Type 63.
     - (2) Flowers violet, grade 1.
       - (a) Plants very early . . . . Type 64.
       - (b) Plants late . . . . Type 65.
   - (iii) Seeds small
     - (1) Flowers white . . . . Type 66.

III. Description of Lentil Types.

Type 1.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Large (3·1 and 1·4× 0·4) green ; 6 pairs of leaflets.

Flowers.—Pink.

Pod.—Bold (1·5×0·5).

Seed.—Intermediate, prussian red, no mottling, occasional speckling, pale yellow hilum.

Type 2.

Habit.— Very early, spreading very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·5 and 1·5×0·4) yellowish green, 6 pairs of leaflets.

Flowers.—White with lilac colour on the veins only.

Pod.—Bold (1·5×0·6).

Seed.—Large, salmon buff, no mottling, occasional sky-grey speckling, grade 1, but always with a speckle at the micropylar end of the hilum.

Type 3.

Habit.— Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·2×0·4) yellowish green, 7 pairs of leaflets.

Flowers.—White with lilac colour on the veins only.

Pod.—Medium (1·4×0·6).

Seed.—Large, vinaceous buff, no mottling, occasional sky-grey speckling grade 1, but always with a speckle at the micropylar end of the hilum.

Note.—All measurements are in cm. In the description of the leaf the first number mentioned is the length of the leaf, the second number is the length of the leaflet and the third number is the breadth of the leaflet. Similarly, in the description of the pod the numbers refer to the length and breadth of the green pod.

TYPE 4.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·3 and 1·2×0·4), light yellowish green, 5 pairs of leaflets.

Flowers.—White with lilac colour on the veins only.

Pods.—Medium (1·3×0·5).

Seed.—Intermediate, vinaceous buff, no mottling, occasional speckling grade 1, but always with a speckle at the micropylar end of the hilum.

TYPE 5.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Large (2·7 and 1·5×0·4) yellowish green ; 6 pairs of leaflets.

Flowers.—White with lilac colour on the veins only.

Pod.—Bold (1·6×0·7).

Seed.—Large, vinaceous buff, sparse cloudy mottling, grade, 1, occasional sky-grey speckling grade 1, but always with a speckle at the micropylar end of the hilum.

TYPE 6.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·1×0·4), dark-bluish-green ; 6 pairs of leaflets.

Flowers.—White.

Pod.—Small (1·1×0·5).

Seed.—Small, vinaceous pink, sparse cloudy mottling, grade 1, no speckling, pale yellow hilum.

TYPE 7.

Habit.—Very early, semi-erect, somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·1 and 1·1×0·4), dark green ; 6 pairs of leaflets ; tendrils small.

Flowers.—White.

Pod.—Small (1·2×0·5).

Seed.—Intermediate, buff pink, heavy cloudy mottling, grade 3, occasional sky-grey speckling grade 1, pale yellow hilum.

TYPE 8.

Habit.—Very early, semi-erect ; somewhat open, with scanty branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (2·8 and 1·6×0·4) yellowish green ; 5 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Bold (1·5×0·7).

Seed.—Large, pale pinkish buff ; heavy cloudy mottling, grade 3, and sparse sky-grey speckling grade 1 ; hilum pale yellow.

TYPE 9.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·3 and 1·5×0·5) yellowish green, 7 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Bold (1·5×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 10.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·4 and 1·4×0·5) light yellowish-green; 6 pairs of leaflets; tendrils small.

Flowers.—Violet grade 2.

Pod.—Bold (1·5×0·7.)

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 11.

Habit. Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·7 and 1·1×0·4) yellowish-green with red tinge at the margin of the leaflets and on the stipules; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 12.

Habit. Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, red colour at the base, angular and hairy.

Leaves.—Small (2·0 and 1·3×0·4), yellowish-green with reddish tinge on the margin of the leaflets and on the stipules; 5 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Medium (1·3×0·7).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 13.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·3×0·5), yellowish-green; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 14.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·5 and 1·4×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·4×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 15.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·4 and 1·5×0·5), yellowish-green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 16.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (2·8 and 1·5 0·5), yellowish-green, slight red tinge at the margin of the leaflets ; 5 pairs of leaflets.

Flowers.—Violet, grade 1.

Pod.—Medium (1·4×0·6).

Seed. Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky grey speckling, grade 1 with a prominent speckle at the micropylar end of the hilum.

TYPE 17.

Habit. - Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·4 and 1·1×0·4), dull green . 5 pairs of leaflets.

Flowers.—Violet, grade 1.

Pod.—Bold (1·5×0·6).

Seed. Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky grey speckling, grade 1, with a prominent speckle at the micropylar end of the hilum.

TYPE 18.

Habit. Early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·9 and 1·3×0·1), deep yellowish green ; 6 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Small (1·0×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 19.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·6 and 1·3×0·4), light yellowish green ; 6 pairs of leaflets.

Flowers.—Violet, grade 1.

Pod.—Bold (1·5×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 20.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (2·9 and 1·4×0·5), green with red tinge on the margins of leaflets and on the stipules ; 5 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Bold (1·6×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with prominent speckle at the micropylar end of the hilum.

TYPE 21.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·2 and 1·4×0·5), deep yellowish-green with slight red tinge at the margin of the leaflets and on the stipules ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 22.

Habit. Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (3·1 and 1·5×0·4), green with red tinge on the margin of the leaflets and on the stipules ; 5 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Bold (1·5×0·6).

Seed. Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 23.

Habit.—Medium in maturity, trailing, profuse branching.

Stem.—Green with red colour at the base, angular and hairy

Leaves.—Large (2·9 and 1·2×0·4), yellowish-green , 6 pairs of leaflets , tendrils small.

Flowers.—Violet grade 1.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 24.

Habit.— Early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·4 and 1·1×0·4), dull green ; 6 pairs of leaflets.

Flowers.—Violet, grade 2.

Pod.—Bold (1·5×0·6).

Seeds.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 25.

Habit. Very early, erect, somewhat closed, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Large (3·4 and 1·3×0·4), light green ; 5 pairs of leaflets. Tendrils small.

Flowers.—White.

Pod.—Small (1·2×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling grade 3, medium sky-grey speckling grade 2, pale yellow hilum.

TYPE 26.

Habit.- Early, semi-erect, somewhat open, profuse branching.

Stem.—Green angular and hairy.

Leaves.—Small (2·0 and 1·2×0·4), dark green ; 6 pairs of leaflets. Tendrils small.

Flowers.—White.

Pod.—Small (1·1×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, pale yellow hilum.

TYPE 27.

Habit.— Early, trailing, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·1 and 1·2×0·5), light green ; 6 pairs of leaflets. Tendrils small.

Flowers.—Violet grade 1.

Pod.—Medium (1·4×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, pale yellow hilum.

TYPE 28.

Habit.—Medium in maturity, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·9 and 1·0×0·3), yellowish-green with slight reddish tinge on the margin of the leaflets and on the stipules ; 6 pairs of leaflets. Tendrils small.

Flowers.—Violet with a pinkish tinge.

Pod.- Small (1·1×0·5).

Seed.—Small, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky grey speckling grade 2, pale yellow hilum.

TYPE 29.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (2·8 and 1·5×0·5), yellowish green with slight red tinge on the margin of leaflets and on the stipules ; 6 pairs of leaflets.

Flowers.—Violet with a light pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 30.

Habit. Very early, semi-erect, somewhat open, profuse branching.

Stem.- Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·3 and 1·5×0·5), yellowish green ; 5 pairs of leaflets.

Flowers.- Violet grade 1, deeper than in any other case, both on the base of the standard as well as on the border ot the wings.

Pod.—Bold (1·6×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 31.

Habit.— Very early, semi-erect, somewhat open, scanty branching.

Stem.- Green, angular and hairy.

Leaves.- Small (1·9 and 1·2×0·4), dull-green ; 5 pairs of leaflets. Tendrils small.

Flowers.—White.

Pod.—Medium (1·3×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 32.

Habit.— Early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base and red splashes on the branches, angular and hairy.

Leaves.—Medium (2·1 and 1·1×0·4), yellowish green. Red tinge on the margin of leaflets and on stipules ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 33.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·1 and 1·1×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 34.

Habit. Medium in maturity, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves. Small (1·9 and 1·0×0·4), deep yellowish green with slight reddish tinge on the margin of the leaflets and on the stipules ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Small (1·2×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 35.

Habit.—Medium in maturity, trailing, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·6 and 1·0×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Small (1·1×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 36.

Habit.—Late, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·9 and 1·0×0·4), yellowish green ; 5 pairs of leaflets, tendrils small.

Flowers.—Violet grade 1.

Pod.—Medium ($1{\cdot}3 \times 0{\cdot}6$).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 37.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium ($2{\cdot}4$ and $1{\cdot}2 \times 0{\cdot}4$), light green ; 6 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Small ($1{\cdot}2 \times 0{\cdot}6$).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 38.

Habit.—Medium in maturity, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small ($2{\cdot}0$ and $1{\cdot}0 \times 0{\cdot}4$), yellowish green ; 5 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Small ($1{\cdot}2 \times 0{\cdot}5$).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 39.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small ($2{\cdot}0$ and $1{\cdot}3 \times 0{\cdot}1$), yellowish green with red tinge on the margin of leaflets and on stipules ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Bold ($1{\cdot}4 \times 0{\cdot}6$).

Seed.—Small, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 40.

Habit.—Very late, trailing, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small ($2{\cdot}1$ and $1{\cdot}0 \times 0{\cdot}3$), yellowish green ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Small ($1{\cdot}1 \times 0{\cdot}5$).

Seed.—Small, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 41.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·5 and 1·4×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Bold (1·6×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, heavy sky-grey speckling grade 3, with a very prominent speckle at the micropylar end of the hilum.

TYPE 42.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·5 and 1·5×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, heavy sky-grey speckling grade 3, with a prominent speckle at the micropylar end of the hilum.

TYPE 43.

Habit.—Very early, semi-erect, somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·3×0·4), dull green; 6 pairs of leaflets ; tendrils small.

Flowers.—White.

Pod.—Medium (1·3×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 44.

Habit.—Very early, semi-erect, somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·0 and 1·1×0·4), green ; 6 pairs of leaflets ; tendrils small.

Flowers.—White.

Pod.—Small (1·1×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 45.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·1 and 1·1×0·4), dark green ; 6 pairs of leaflets ; tendrils small.

Flowers.—White.

Pod.—Small (1·2×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

Type 46.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·4 and 1·1×0·4), dark green ; 7 pairs of leaflets.

Flowers.—White.

Pod.—Small (1·1×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

Type 47.

Habit.—Early, trailing, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·2×0·4), dark-bluish-green ; 7 pairs of leaflets.

Flowers.—White.

Pod.—Small (1·1×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

Type 48.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·1 and 1·5×0·5), yellowish green with a slight reddish tinge on the margin of the leaflets and on the stipules ; 5 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Bold (1·4×0·7).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

Type 49.

Habit.—Early, semi-erect, open somewhat, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (2·0 and 1·1×0·1) yellowish green with slight reddish tinge on the margin of the leaflets and on the stipules, 7 pairs of leaflets.

Flowers.—Violet with a light pinkish tinge.

Pod.—Small (1·2×0·6).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

Type 50.

Habit.—Early, semi erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·3×0·6), dull green; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet with a pinkish tinge.

Pod.—Small ($1{\cdot}1 \times 0{\cdot}6$).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 51.

Habit.—Medium in maturity, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base.

Leaves.—Small ($2{\cdot}1$ and $0{\cdot}9 \times 0{\cdot}3$), deep yellowish green with reddish tinge on the margin of the leaflets and on the stipules ; 7 pairs of leaflets ; tendrils small.

Flowers. Violet grade 1.

Pod.—Small ($1{\cdot}2 \times 0{\cdot}6$).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 52.

Habit. Late, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large ($3{\cdot}0$ and $1{\cdot}1 \times 0{\cdot}4$), dark green ; 6 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.- Medium ($1{\cdot}3 \times 0{\cdot}6$).

Seed. Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 53.

Habit. Very late, semi-erect, somewhat open, bushy, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small ($1{\cdot}6$ and $1{\cdot}0 \times 0{\cdot}3$), yellowish green , 6 pairs of leaflets.

Flowers.– Violet grade 2.

Pod.—Small ($1{\cdot}2 \times 0{\cdot}6$).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with pale yellow hilum.

TYPE 54.

Habit.-- Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Small ($2{\cdot}0$ and $1{\cdot}2 \times 0{\cdot}4$), light green ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 2.

Pod.—Small ($1{\cdot}2 \times 0{\cdot}5$).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 55.

Habit.—Very early, semi-erect, somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Small ($2{\cdot}1$ and $1{\cdot}0 \times 0{\cdot}4$), dark green ; 6 pairs of leaflets ; tendrils small.

Flowers.—White.

Pod.—Small ($1{\cdot}1\times0{\cdot}5$).

Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 56.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium ($2{\cdot}4$ and $1{\cdot}2\times0{\cdot}4$), green; 6 pairs of leaflets; tendrils small.

Flowers.—White.

Pod.—Small ($1{\cdot}2\times0{\cdot}5$).

Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 57.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium ($2{\cdot}3$ and $1{\cdot}1\times0{\cdot}4$), green; 6 pairs of leaflets; tendrils small.

Flowers.—White.

Pod.—Small ($1{\cdot}2\times0{\cdot}6$).

Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 58.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small ($2{\cdot}0$ and $0{\cdot}9\times0{\cdot}3$), yellowish green; 6 pairs of leaflets; tendrils small.

Flowers.—Violet with a pinkish tinge.

Pod.—Small ($1{\cdot}1\times0{\cdot}5$).

Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 59.

Habit.—Early, erect, somewhat closed, scanty branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium ($2{\cdot}2$ and $1{\cdot}1\times0{\cdot}4$), yellowish green; 5 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Bold ($1{\cdot}4\times0{\cdot}6$).

Seed.—Large, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 60.

Habit.—Early, semi-erect somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·7 and 1·4×0·5), dull green, 5 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Medium (1·4×0·6).

Seed.—Large, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 61.

Habit.—Very early, erect, somewhat closed, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Very large (3·8 and 1·3×0·4) light green; 6 pairs of leaflets; tendrils small.

Flowers.—White.

Pod.—Small (1·2×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 62.

Habit. Early, spreading, very much open, profuse branching.

Stem. Green, angular and hairy.

Leaves.—Medium (2·3 and 1·1×0·5), green; 7 pairs of leaflets.

Flowers.—White.

Pod.—Small (1·2×0·6).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 63.

Habit.—Early, trailing, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·1 and 1·1×0·5), dark green; 7 pairs of leaflets.

Flowers.—White.

Pod.—Small (1·1×0·6).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 64.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·6 and 1·5×0·5), light yellowish green; 6 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Bold (1·5×0·7).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a prominent speckle at the micropylar end of the hilum.

TYPE 65.

Habit.—Late, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular, and hairy.

Leaves.—Medium (2·5 and 1·1×0·4), yellowish green ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Bold (1·4×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 66.

Habit.—Very early, spreading, open very much, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·8 and 1·1×0·4), dark green ; 5 pairs of leaflets.

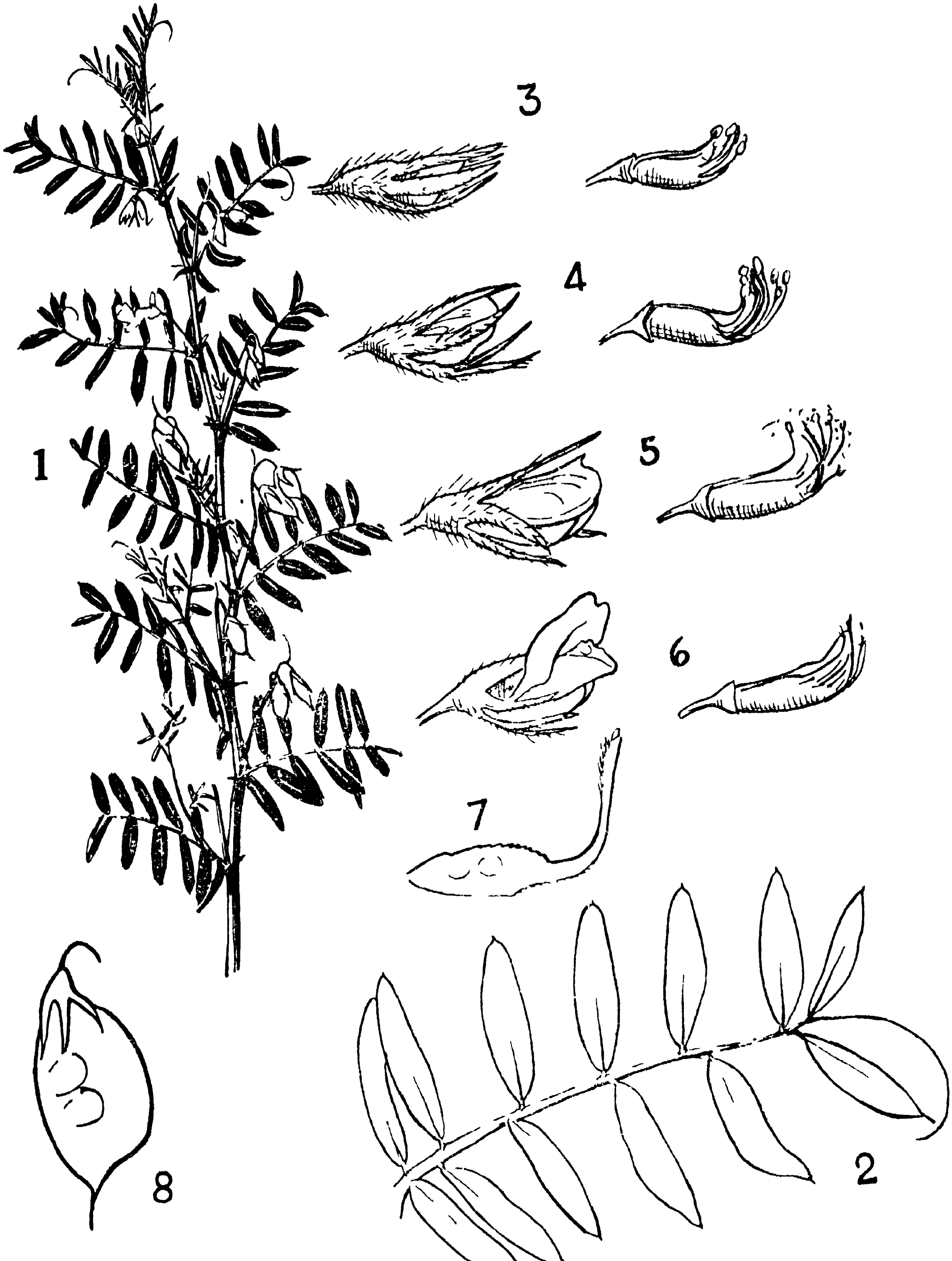
Flowers.—White.

Pod.—Small (1·1×0·5).

Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

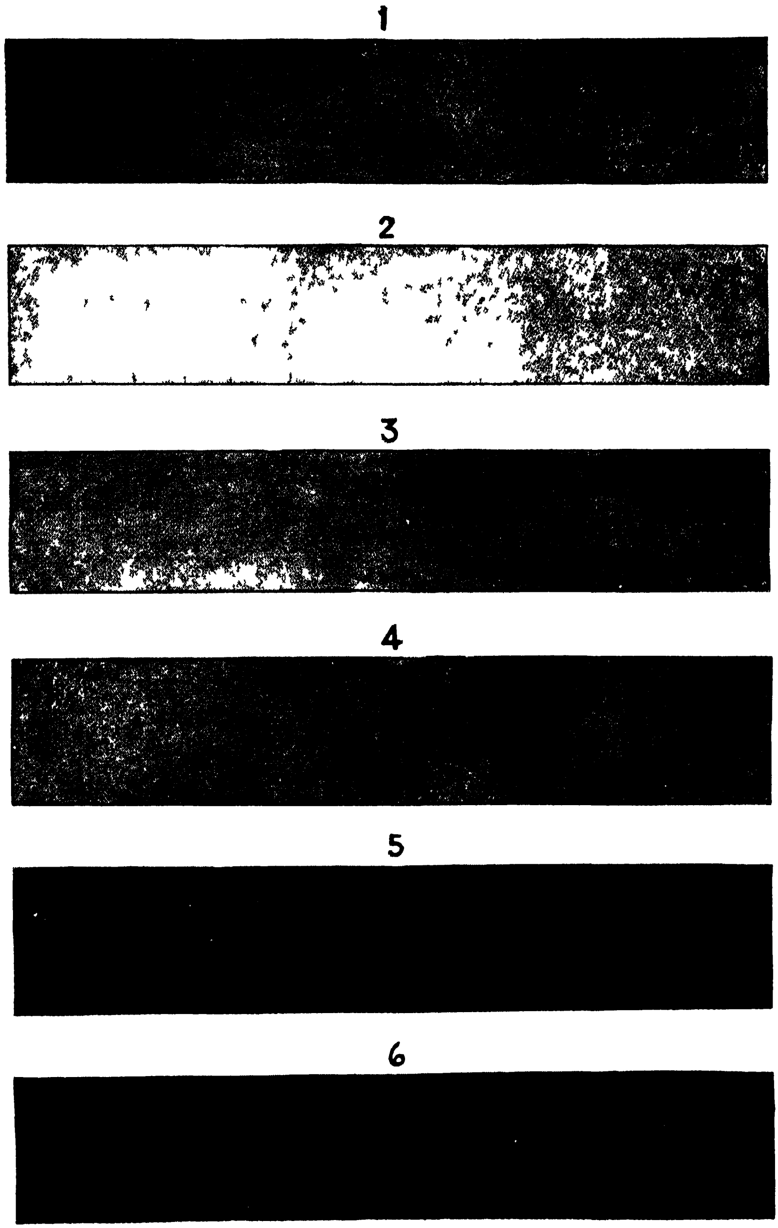
MGIPC—M—III-1-94—1-2-29 -650.

PLATE I.



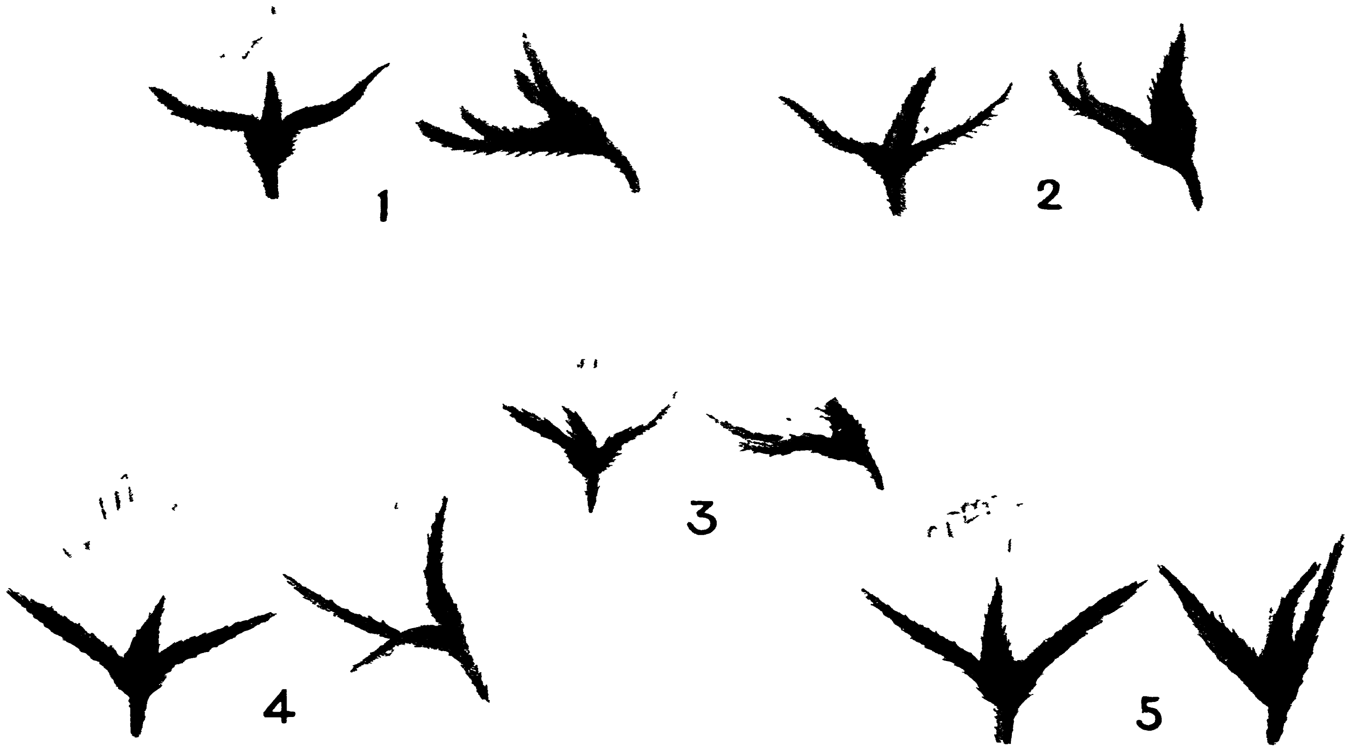
Morphological details in Lentils.

Fig. 1. Branch showing the arrangement of leaves, flowers and pods.
Fig. 2. Leaf.
Figs. 3-8. Different stages in the development of the flower bud. Fig. 5 shows the bud just before opening—a stage when the pollen grains burst and fertilise the flower.



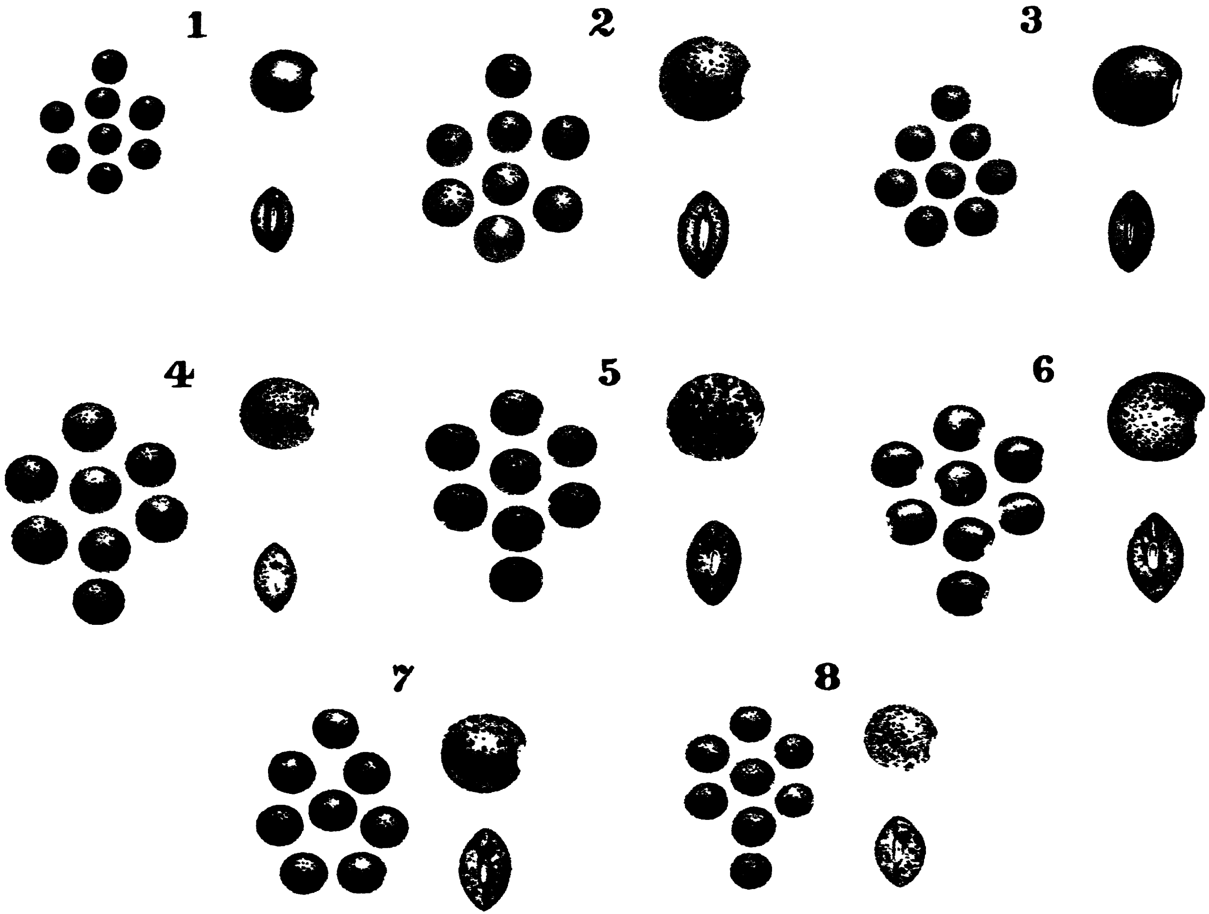
Tints of foliage colour when seen in mass.

1, Dull (light bluish) green, 2, Light yellowish green, 3, Yellowish green, 4, Green; 5 Dark green; 6, Dark bluish green.



The range in flower colour.

1, White—Type 6; 2, White with lilac colour on the veins—Type 2; 3, Pink—Type 1; 4, Violet with a pinkish tinge—Type 8; 5, Violet, Grade I—Type 9.



Seed coat colour and markings.
1, Type 1; 2, Type 2; 3, Type 5; 4, Type 17; 5, Type 41; 6, Type 19; 7, Type 33; 8, Type 58.

PLATE IV.

PUBLICATIONS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

TO BE HAD FROM

THE MANAGER, GOVERNMENT OF INDIA CENTRAL PUBLICATION BRANCH, IMPERIAL SECRETARIAT BUILDING, 3, GOVERNMENT PLACE, WEST, CALCUTTA;

THE OFFICE OF THE AGRICULTURAL ADVISER TO THE GOVERNMENT OF INDIA, PUSA, BIHAR,

AND

ALL AGENTS FOR SALE OF GOVERNMENT PUBLICATIONS.

A complete list of the publications of the Imperial Department of Agriculture in India can be obtained on application from the above-mentioned.

These publications are :—

1. The *Agricultural Journal of India*. A Journal dealing with subjects connected with agricultural economics, field and garden crops, economic plants and fruits, soils, manures, methods of cultivation, irrigation, climatic conditions, insect pests, fungus diseases, co operative credit, farm implements, and other agricultural matters in India Illustrations, including coloured plates, form a prominent feature of the Journal. It is edited by the Agricultural Adviser to the Government of India, and is issued once every two months or six times a year *Annual subscription*, Rs. 6 or 9*s*. 6*d*. including postage Single copy Rs 1 8 or 2*s*
2. The *Journal of the Central Bureau for Animal Husbandry and Dairying in India*. A quarterly dealing with cattle breeding, dairying, cultivation and storage of fodder crops, animal nutrition, and other aspects of animal husbandry. It is edited by the Agricultural Adviser to the Government of India. *Annual subscription*, Rs 2 8 0 Single copy As. 10.
3. Scientific Reports of the Agricultural Research Institute, Pusa.
4. Review of Agricultural Operations in India.
5. Proceedings of the Board of Agriculture in India.
6. Proceedings of Sectional Meetings of the Board of Agriculture.
7. Memoirs of the Imperial Department of Agriculture in India
    - (*a*) Botanical Series.
    - (*b*) Chemical Series.
    - (*c*) Entomological Series.
    - (*d*) Bacteriological Series.
    - (*e*) Veterinary Series.
8. Bulletins issued by the Agricultural Research Institute, Pusa.
9. Books.

The following are the publications of the last two years :—

Scientific Reports of the Agricultural Research Institute, Pusa (including the Reports of the Imperial Dairy Expert, the Physiological Chemist, Government Sugarcane Expert, and Secretary, Sugar Bureau), for the year 1926 27. Price, Rs. 1-14 or 3*s*. 3*d*.

Scientific Reports of the Agricultural Research Institute, Pusa (including the Reports of the Imperial Dairy Expert, Physiological Chemist, Government Sugarcane Expert, and Secretary, Sugar Bureau), for the year 1927-28. Price, Rs. 2-6 or 4*s*. 3*d*.

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BY

RAO BAHADUR T. S. VENKATRAMAN, B.A.,
Government Sugarcane Expert

AND

R. THOMAS

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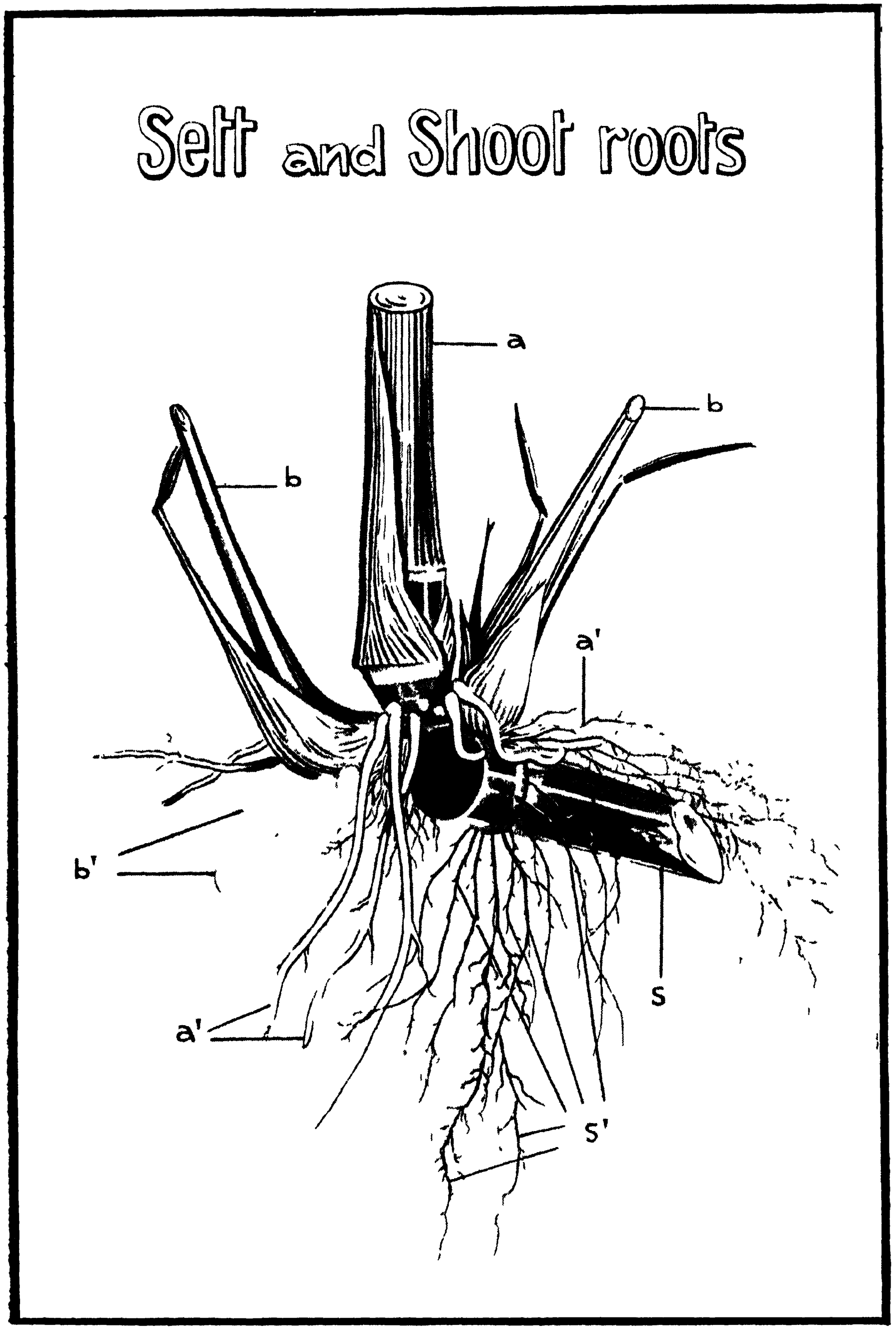


S. The original planted sett.
S^1. *Sett* roots (formed from the sett).
a. The first shoot developed from the sett.
a^1. *Shoot* roots developed from *a*.
b. Other shoots developed from *a*.
b^1. *Shoot* roots developed from *b*.

STUDIES OF SUGARCANE ROOTS AT DIFFERENT STAGES OF GROWTH.

BY

RAO BAHADUR T. S. VENKATRAMAN, B.A.,
Government Sugarcane Expert

AND

R. THOMAS

(Received for publication on 3rd July 1928.)

I. Early (germination) stages—period of Sett roots.

(1) *Sett roots and their formation.*

In ordinary cultivation the sugarcane is grown from cuttings or '*setts*'* as they are also called. To start germination these cuttings are planted in soil already containing a sufficiency of moisture to germinate the buds; or, where the soil moisture is deficient, periodic and suitable irrigations are given to maintain the moisture in the soil. When the sett comes into contact with the moisture in the soil, it absorbs the moisture and certain changes take place in it. Usually, one of the first activities in the planted sett is the development of roots from the translucent dots or 'root eyes' found at the base of every cane joint. These translucent dots are really the incipient or resting root tips and are often the first to be called into activity during germination. It is proposed in this paper to call these roots '*sett*' roots because of their origin from setts and in contrast with '*shoot*' roots to be described later.

(2) *Number of root eyes developing sett roots.*

Sugarcane varieties show interesting differences in the number and length of sett roots that are developed during the first stages of germination (Table I and Pl. I). The number of sett roots formed is large in the case of the tropical canes as compared with that in the Indian canes. The now popular Coimbatore seedlings mostly resemble the Indian canes apparently because of their parentage, while the P. O. J. seedlings thus far studied tend more towards the tropical types. *Saccharum spontaneum* is rather different from *Saccharum arundinaceum* in this respect as seen from Plate I which was prepared from photographs taken sixteen days after planting.

* In publications from Madras where this term is most commonly used, it is sometimes spelt '*set*' and at other times 'sett'. The latter spelling has been adopted to keep it distinct from the word with one 't'.

It needs to be mentioned here that the Indian canes show differences according to the group to which they belong. The canes belonging to the Pansahi group develop the fewest number of sett roots and a more detailed study of the rooting phenomena might throw some light on the phylogenetic relationships of the different groups of canes. The Java cane *Kassoer* develops a small number of sett roots suggesting its derivation from *Sacch. spontaneum*.

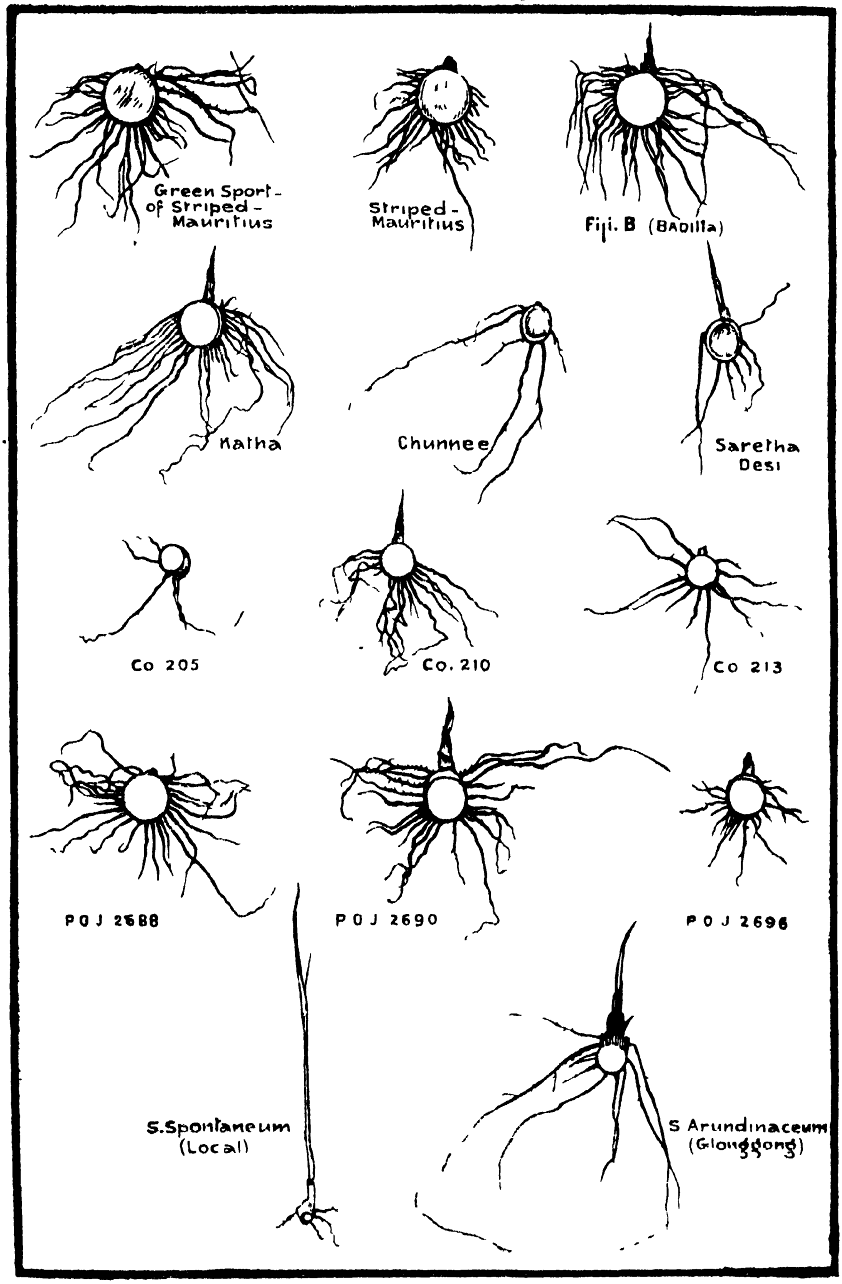
In certain cane seedlings derived from *Sacch. spontaneum* as also in *Sacch. spontaneum* itself all the root eyes do not take part in the first formation of sett roots (Pl. I, figs. of *Sacch. spontaneum* and Co. 205). Some of the root eyes continue dormant and develop roots later on, should the need arise. This would appear to be a definite and valuable provision against possible adverse conditions during the early stages of growth. It is as if the plant were reluctant 'to place all its eggs in one basket' in the matter of the formation of the first batch of sett roots.

TABLE I.

Number of sett roots developed during germination.

Name of variety	Group		Number of sett roots developed ten days after sowing
			(Average of 20 countings)
Striped Mauritius	Tropical canes		56·2
Green Sport of Striped Mauritius			50·3
Badila (Fiji B)			34·9
B. 254			30·6
B. 3412			13·0
Kaludai Boothan			42·3
Katha	Saretha group	Indian canes	31·9
Chunnee			6·8
Saretha desi			10·7
Ketari	Pansahi group.		1·5
Chinia			2·8
Uba			1·6
Sewari	Nargori group		6·6
Nargori			10·8
Manga			15·5

Germination: Early stages.



Sett root development sixteen days from sowing (from photographs). Co. 205 is a hybrid with *Sacch. spontaneum*. Differences exist between varieties in the number as well as in the length of sett roots. **There is no correlation between sett root development and sprouting of buds.**

Note.—Fiji B is the Indian name for Badila.

TABLE I—*contd.*

Number of sett roots developed during germination contd.

Name of variety	Group	Number of sett roots developed ten days after sowing
		(Average of 20) countings)
Co. 205	Coimbatore seedlings	3·2
Co. 210		21·2
Co. 213		8·9
Co. 281		7·4
P. O. J. 1547	P. O. J. Seedlings	21·5
P. O. J. 2631		23·4
P. O. J. 2688		25·6
P. O. J. 2690		28·5
P. O. J. 2696		19·1
Saccharum spontaneum	Wild Saccharums	2·3
Sach. arundinaceum; (Glonggong of Java)		7·7

(3) *Bud sprouting not correlated with sett root development.*

From general considerations it should be an advantage to the young plant to start with an early development of a fair number of sett roots. Such a development (of sett roots) would enable the plant to obtain its nutrition from the soil earlier than in the case of varieties which develop these roots at a later stage. In the latter case the developing shoot will have to depend on the food stored in the sett during its earlier stages of development and till the sett roots are formed and establish connection with the soil.

The varieties belonging to the Pansahi group of Indian canes develop sett roots late. In certain of them the bud attains a fair amount of growth before the setts begin to produce roots. There is thus no direct relation between the very first stages of bursting and shooting of the buds and the development of roots from the sett. The words 'bursting' and 'shooting' are used deliberately in contrast to a proper and efficient germination, for which sett roots would appear to be essential.

(4) *Sett roots essential for proper bud germination.*

That, sett roots are essential, for a proper germination and development of the bud into a shoot has been shown in a previous publication.[1] It was there indicated

[1] Venkatraman, T. S. Studies in Sugarcane Germination. *Agri. Jour. India*, Vol. XXI, pt. 2, p. 101

that the bud, however carefully sown and tended, would not germinate properly and develop into a functioning shoot, unless the bud had attached to it at least one root eye with the possibility of developing at least one sett root. It therefore follows that, whereas for the swelling, the bursting and early stages of shooting, the presence of sett roots is not apparently absolutely necessary, their presence is essential for the proper germination and growth of the bud.

(5) *Quality of irrigation water and its effect on sett root development.*

It is well known that the cane is particularly susceptible to the quality of irrigation water[1]—though certain varieties appear to be capable of taking from the soil large quantities of saline matter. Saline waters exert a harmful effect on germination by retarding the formation and development of sett roots (Pl. II). Care should therefore be taken to irrigate the canes with water of good quality during the earliest stages of germination. The check in growth resulting from irrigation with saline water during the early stages of germination is well seen from Table II.

TABLE II.

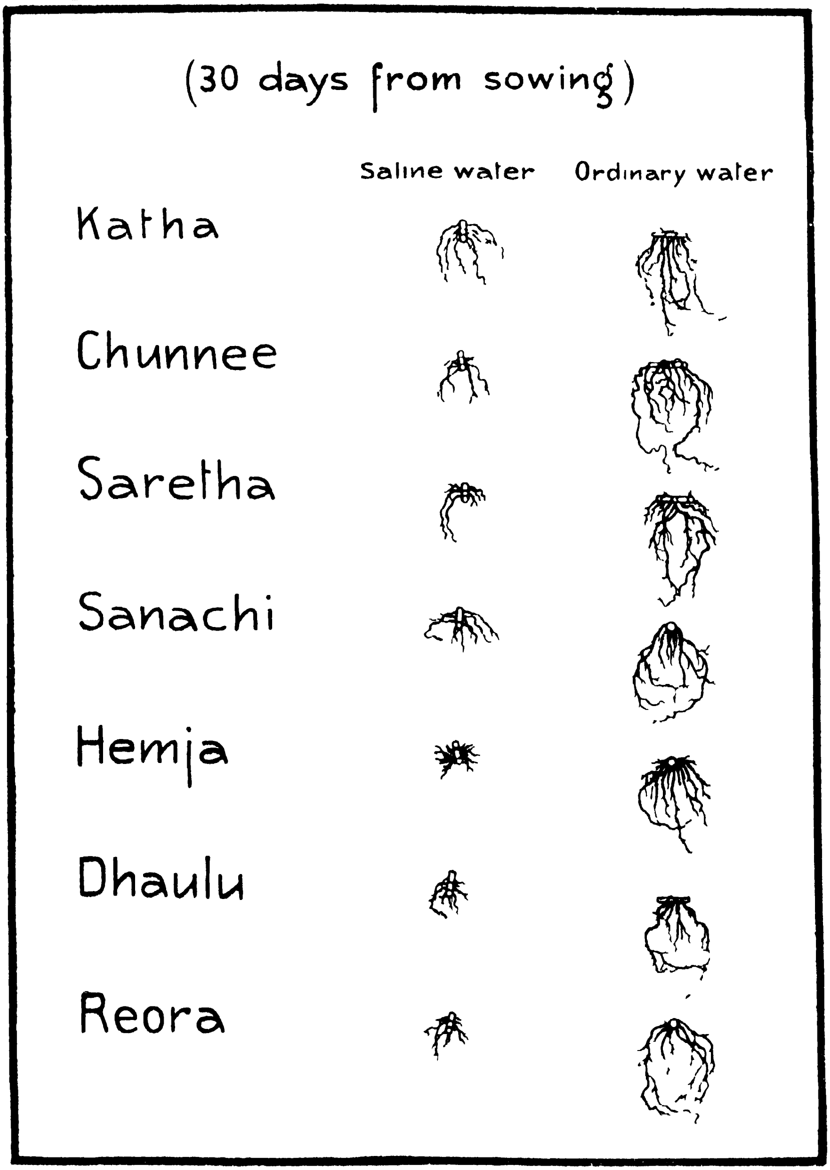
Quality of irrigation water and its effect on sett root development. (Weight of shoots and roots: Plants 20 days old.)

Variety	Irrigated with ordinary water			Irrigated with saline water		
	No. of plants examined	Average dry weight in grammes		No. of plants examined	Average dry weight in grammes	
		Shoot portion	Root portion		Shoot portion	Root portion
Katha . . .	5	0·470	0·160	2	0·210	0·075
Chunnee . .	6	0·445	0·120	4	0·205	0·020
Saretha . .	6	0·265	0·087	5	0·191	0·036
Dhaulu . . .	6	0·353	0·153	4	0·128	0·045
Hemja . . .	5	0·300	0·070	5	0·214	0 034
Rheora . . .	6	0·150	0·053	All plants unhealthy.		
Sanachi . .	6	0 421	0·078	5	0 176	0 012

The 'ordinary' water in the above experiments contained 78·0 total solids in 100,000 parts. The 'saline' water contained a little over 500 parts. The salts were chiefly sodium chloride and sodium carbonate.

[1] Krishnamurthi Rao K Irrigation Water for Sugarcane Cultivation *Year Book, Madras Dept Agri*, 1920-21 p 97

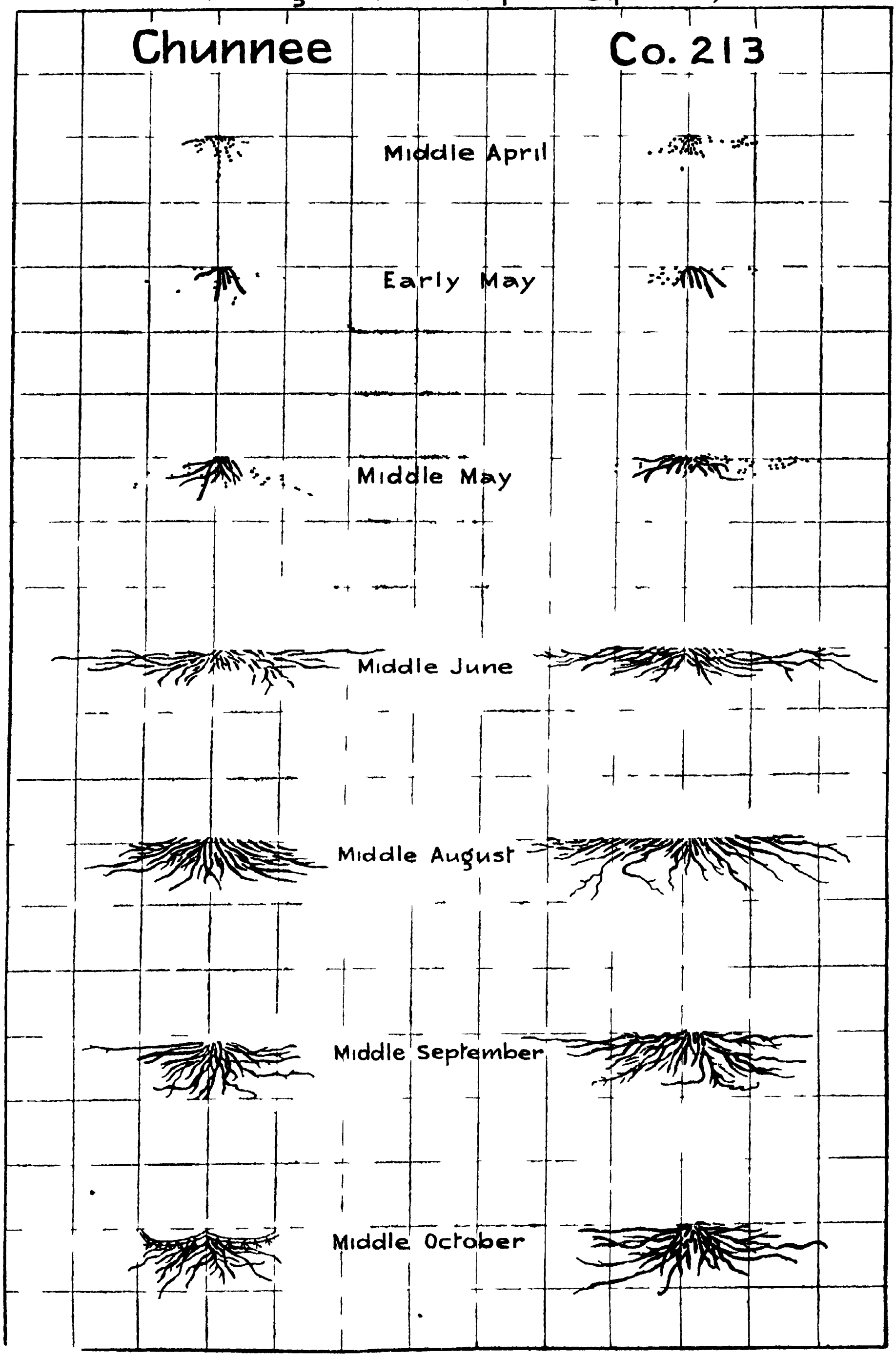
Irrigation water & sett roots development.



There is a marked retardation in *sett* root development when planted *setts* are irrigated with saline water. **Irrigation with saline water should therefore be avoided.**

Periodic Root dissections.

(Back ground two feet squares)



The above sketches are of average specimen of four dissections in the field The canes were planted on 1st April. Note the gradual death of *sett* roots (dotted lines), as the plants grow Owing to the constant production of new roots, the root system of the cane varies from time to time **A detailed knowledge of root systems at different stages would be a valuable guide to the conducting of manurial and cultural operations with**

II. LATER STAGES IN GROWTH—SHOOT ROOTS AND THEIR DEVELOPMENT.

(1) *Formation of shoot roots.*

Although, as already mentioned, sett roots are apparently essential for germination and the early stages in the development of the bud into a shoot, these roots generally die after a time (Pl. III and Table III). On account of their temporary nature, the corresponding roots in cereals have been styled "*temporary roots*" by other authors.[1] Latter on, the growing plant is dependent for its nutrition on other roots which develop later from the shoots, be they the first formed 'mother' shoots or other shoots which are subsequently developed from this 'mother' shoot. It is proposed to call these '*shoot*' roots, because of their origin from *shoots* and not from *setts*. These shoot roots differ in certain respects from the first formed sett roots; and certain of these differences will be briefly dealt with in a subsequent section of this paper. The shoot roots of the cane plant, in a way, correspond to the '*nodal*' roots of barley and the sett roots to the '*seminal*'.[2]

The period during which sett roots function differs in the different varieties. The sett roots of *Sacch. spontaneum* function the longest and certain of the hybrids with *Sacch. spontaneum* —like Co. 205[3]— have shown this character.

TABLE III.

Relative weights of sett and shoot roots at different stages of growth.

(Average of 5 plants.)

Name of variety	Age of plant	Dry weight in grammes	
		Sett roots	Shoot roots
	Days		
Katha	36	0·3	2·9
	58	0·2	10·2
	78	0·1	18·4
	104	0·1	31·3
Saretha	37	0·8	2·9
	58	0·7	11·7
	81	0·4	19·6
	104	0·1	27·2
Hemja	39	0·4	2·2
	60	0·5	7·5
	81	0·4	9·7
	105	0·2	19·4
E. K. 2	40	0·9	1·2
	64	0·5	3·7
	83	0·5	7·6
	110	0·3	17·3

[1] Wiggans, R. G. *Jour. American Soc., Agronomy*; Vol VIII, 1916, p. 31.
Jackson, V. G. *Ann. Bot.*, Vol. XXXVI, 1922, p. 21.

[3] Venkatraman, T. S., and Vittal Rao, U. Coimbatore Seedling Canes. *Agri. Jour. India*, Vol. XXIII, pt. 1, p. 28.

(2) *Growth of plant dependent on shoot root development.*

The shoot roots play an important *role* in the further growth and development of the cane plant and constitute the sole root system of the plant after the death of the sett roots. If under experiment a growing cane plant is continuously deprived of its shoot roots as they develop and made to depend entirely on the first formed sett roots, its vigour suffers markedly in comparison with the control (Pl. VII, Figs. 6 to 9).

In one experiment, where ten plants of Co. 213 were grown on sett roots alone and another ten plants in the normal manner -*i.e.* on sett and shoot roots– it was found that the sett root plants did not arrow when the season came round. The control plants arrowed freely. These plants were five months old when the arrowing season arrived.

The vigour of growth of shoot roots differs according to the variety, being generally greater in the Indian canes as compared with the tropical kinds. Certain of the Coimbatore seedlings take more after the Indian canes. In the varieties studied, a positive correlation has been definitely indicated between shoot-root vigour and the vegetative vigour of the plants. (Pl. IV.)

(3) *Mode of branching (tillering) in the sugarcane.*

To understand clearly the root system of the adult plant, consisting almost entirely of shoot roots, it is necessary to notice very briefly here the process of branching or tillering as it takes place in the sugarcane. This subject has been dealt with very elaborately by Dr. Barber in one of his publications.[1]

What is known ordinarily as the germination of a planted sett is really the germination and sprouting of the bud or buds contained in the sett. These buds—the original buds on the sett -soon develop into shoots, an incipient stem or cane being formed in each at a very early stage in the development of the shoot. These incipient canes can be seen by taking a vertical section of the shoots, when they will be found to possess both incipient root eyes as well as incipient buds. These incipient root eyes soon give rise to roots—the first 'shoot' roots of the plant and the buds develop into 'daughter' shoots. The 'daughter' shoots in their turn develop other shoots—the 'grand-daughter' shoots—and the process continues till a fairly late stage in the life of the plant. This results in the formation of what is ordinarily known as the 'Sugarcane clump,' such a clump being formed of (1) the mother shoot, (2) a certain number of 'daughter' shoots, (3) a greater number of 'grand-daughter' shoots and so on. Each of the shoots in the clump possesses incipient root eyes containing root primordia and therefore capable of developing into roots under favourable conditions of growth.

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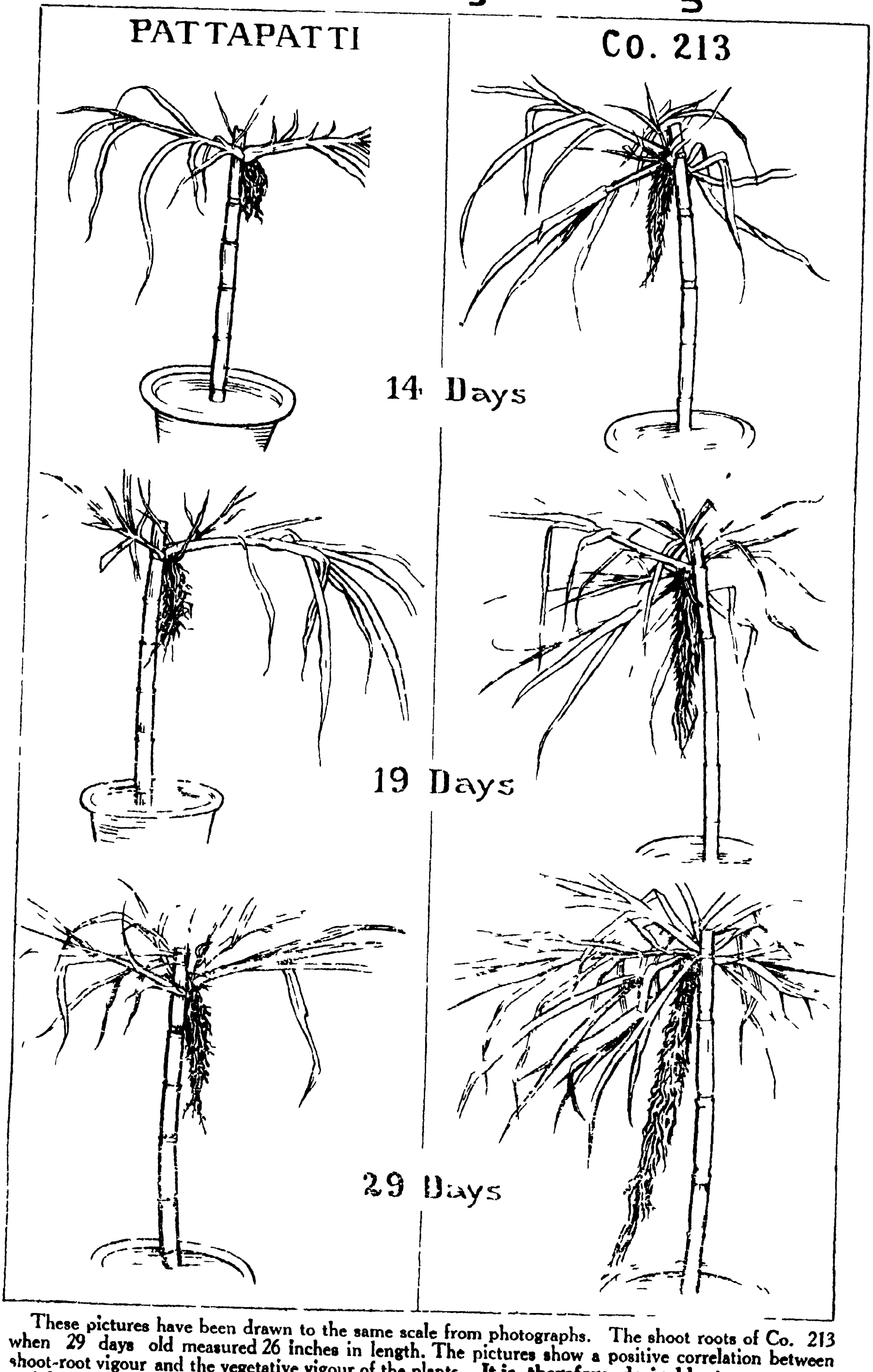
[1] Barber, C. A. Tillering or Underground Branching; *Mem. Dept. Agri. India, Bot. Ser.*, Vol. X, No. 2.

Shoot Roots – Vigour of growth



These pictures have been drawn to the same scale from photographs. The shoot roots of Co. 213 when 29 days old measured 26 inches in length. The pictures show a positive correlation between shoot-root vigour and the vegetative vigour of the plants. **It is therefore desirable to encourage quick and vigorous development of shoot roots.** Earthing up the crop at the right time is one method of doing this.


1
a
b
2
3

1a. Sett roots developed after the sett had established organic connection with the active functioning leaves of the top shoot. 1b. Sett roots originally developed to start the top shoot.

2. Plant of Co 213 five months old and growing at a height of 4 ft. above the soil, the sole connection with the soil being the 2 old roots shown. The leaves have turned pale and the plant is about to die out.

3. The same plant at $6\frac{1}{2}$ months showing fresh green shoots as the result of the formation of new roots.

To get a good crop the sugarcane should be given facilities for the frequent production of new roots.

III. The root system of the adult plant.

We have just seen that the adult plant consists of a mass of shoots of different orders, each of the shoots possessing incipient root eyes capable of developing into roots under favourable conditions of growth. In ordinary cultivation the basal nodes of most of the shoots are either inside the soil or very close to it. The periodic earthings which are given to the crop bring these basal portions and hence the incipient root eyes under the soil and thus create favourable conditions for the development of fresh roots from the root eyes. As the result of this, fresh roots are more or less continuously thrown out by the clump into the soil.

(1) *Continuous development of new roots.*

Like the sett roots the shoot roots also die after a time, their place being taken by other fresh roots, developed from other nodes in the same shoot or from other daughter or grand daughter shoots. This explains the rather considerable changes in the habit and plan of root systems in the periodic root dissections (Pl. III). If the soil were transparent and one could watch the continuous root activities of the sugarcane clump, one would notice an almost continuous production of fresh roots, the older roots dying out and getting incorporated with the soil. The authors realized this aspect of the root activities of the cane plant for the first time when they grew canes in water culture nd the root development thus became clear for continuous observation.[1] This was afterwards fully borne out by periodic root dissections in the field.

Whenever there is a chance and from the mode of branching already described there are plenty of chances under ordinary crop conditions the cane plant prefer to develop fresh roots for obtaining nourishment rather than depend upon the older ones. By a clever arrangement, originally designed by the junior author,[2] it has been possible to grow canes away from the soil, on a definite number of roots and without any possibility of other new roots developing. Under such conditions the plants gradually lost vigour and died out. When, however, a plant thus starved for fresh roots was given opportunities to develop them, the plant at once grew on in a remarkable manner (Pl. V, Figs. 2 & 3). The importance of a continuous development of fresh roots in the life of the sugarcane plant is thus obvious.

(2) *Advantages resulting from the continuous production of fresh roots.*

This constant and almost continuous production of fresh roots enables the cane plant to adjust its root system to the prevailing environmental conditions with a considerable degree of nicety. When periodic dissections are made of the

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[1] Venkatraman, T. S., and Thomas, R. Simple contrivances for studying root development in Agricultural crops. *Agri. Jour. India*, Vol. XIX, pt 5, p. 509.

[2] Thomas, R. A Method of studying the roots of Sugarcane. *Agri. Jour. India*, Vol. XXII, pt. 2, p. 138.

same plant or variety, it is found that they greatly differ from one another according to the conditions of growth obtaining at each period of dissection. This is well illustrated by the dissections figured in Pl. III. It is interesting to see how the root system which was comparatively shallow during middle June-the period of a comparatively high water table in the particular field at Coimbatore—changes into a much deeper root system during September—October as the water table drops. In the case of a plant with a more permanent root system this adjustment to an altered set of environmental conditions would be made by the development of a set of lateral roots growing towards places of available moisture. In the cane, however, the new roots which are constantly formed are able to direct themselves almost immediately towards points of vantage in the soil. A realization of this phenomenon in the sugarcane has enabled the authors to understand certain otherwise puzzling features in the root system of the same plant or variety at different periods.

(3) *The adult root system.*

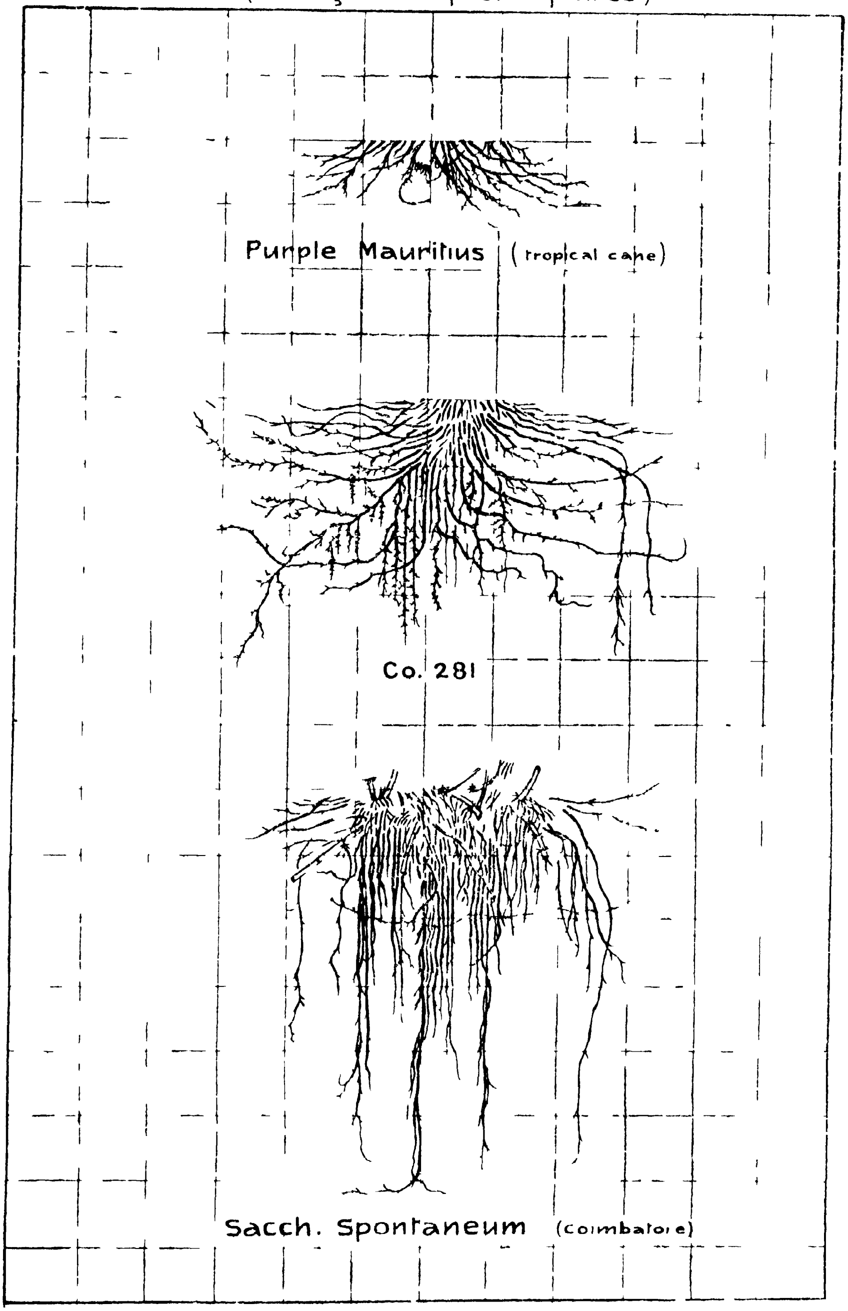
Root systems of sugarcanes show characteristic differences according to the variety to which they belong; and a knowledge of their mode of development is often useful in deciding about the suitability of a new cane to a given set of conditions.

Most tropical types have developed a comparatively surface system necessitating a high type of cultivation for their successful growth. Most Indian canes, on the other hand, develop a deeper system and possess besides, other characteristics which render it possible to grow them under comparatively unfavourable conditions. An ideal root system, conducive to the obtainment of maximum results, would be one which is able to tap the surface as well as the deeper layers of soil for plant food. Somewhat of an approach to this ideal *viz.*, the root system of Co. 281 is figured in Pl. VI. The root systems of a tropical cane (Purple Mauritius) and the grass *Sacch. spontaneum* all grown under the same conditions have also been included in the Plate for comparison.

It should ultimately be possible to work out for each cane its characteristic root system which, besides indicating the conditions under which the variety is likely to do its best, would help to guide the cultivation operations with the maximum of advantage to the crop. For instance, if it is known when and where a particular variety under cultivation develops its series of new roots, the manuring and cultural operations could be timed with the maximum of advantage to the growi crop. It needs to be mentioned, however, that the task is rather laborious, as the root development is profoundly and continuously influenced by environmental conditions; and a very large number of dissections under different conditions of growth would be needed to arrive satisfactorily at the typical root system of a given cane. Though the task is a laborious and time consuming one, it is well worth doing, because of its practical utility in agricultural operations.

Adult Root systems

(Back ground foot squares)



Note the marked difference in the three root systems shown above. The roots of Purple Mauritius are shallow, and of *Sacch. spontaneum* deep. Co. 281—which, in the words of Dr. Earle, has established at Cuba " a record of which any variety may well be proud " possesses shallow as well as deep roots. One of the great grand parents of Co. 281 is *Sacch. spontaneum* ; and it is suggested that the deep roots are derived from this parentage. **Hybridization of sugarcanes with the object of securing a desirable root system is a promising line of work for the future.**

IV. Sett versus Shoot roots.

In the earlier sections of this paper the roots of the sugarcane plant were classified (we believe with some justification) into "*Sett*" and "*Shoot*" roots. We now propose to consider the main differences between the two kinds of roots and seek for any reasons that might explain the observed differences.

(1) *Points of difference.*

(*a*) *Thickness.* One readily noticed difference between sett and shoot roots is the greater thickness of the latter (Frontispiece). Amongst the shoot roots themselves there is often a gradual increase in thickness as the plant advances in growth. The shoot roots arising from the "daughter" shoots are thicker than those from the "mother" shoot, those from the "grand-daughter" shoots still thicker than those from the "daughter" shoots and so on (Frontispiece)[1]. An increase in thickness means an increase in circumference, a corresponding increase in root surface and hence again in the number of root hairs that can be developed. As the absorptive power of roots depends ultimately on the number of root hairs developed— other things being equal it is evident that as absorptive organs the shoot roots are better organized than sett roots.

When it is remembered that there exists a considerable quantity of plant food stored in the joints or internodes of the planted sett, it is admissible to suggest that the sett roots have another function besides the absorption of plant food from the soil. Anchorage suggests itself, as one watches setts germinating on the sides of a rapidly flowering irrigation channel or other watercourse. The arrangement of these roots in the form of a circle round each node would enable them to perform this function in an admirable manner.

(*b*) *Power of soil penetration.* The shoot roots possess larger and, apparently also, stronger root caps than sett roots and are able to pierce the soil with greater ease.* Their greater thickness and the vigour with which they are developed render them efficient as piercing organs. A more detailed study of the histology and physiology of sugarcane roots is now in hand; and it is hoped later to make this the subject of another publication.

(*c*) *Density.* If at any stage the sett and shoot roots of a cane plant are separately collected, it is found that the shoot roots are lighter than the sett roots which are more fibrous (Table IV). Though regular weights have not been recorded, it is probable that the later formed shoot roots would be lighter than the earlier ones.

(*d*) *Growth.* But perhaps the most important difference between the two classes of roots --a difference which is of importance in the growth of the plant is their

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[1] Venkatraman, T. S., and Thomas, R. Sugarcane Breeding Technique—Isolation of live arrows from undesired pollen through artificial rooting of canes. *Agri. Jour. India*, Vol. XXI, pt. 3, Plate VI.

* Differences have been noticed between shoot roots of different varieties in their power of penetration into various soils.

relative power of growth. Under ordinary crop conditions, the two classes of roots become intertwined with one another and it is not possible to separate them easily with much claim to accuracy. With the special method of the Junior author already referred to, it is now possible to grow the two classes of roots altogether separate from each other and even feed them in two different ways, if the plan of the experiment needed it. Plate VII, Figs. 1 to 5 illustrate the greater amount of growth from shoot roots as compared with that from sett roots. Two plants of Co. 213 were first started on sett roots from the bottom nodes, the setts—two budded setts in this case—being planted vertically in pots. Fig. 1 represents the growth from the sett roots of the bottom nodes and it will be noticed that they are about equal in the two top plants in Plate VII. Fig. 2 represents growth from 6 sett roots developed from the top node and Fig. 3 growth from two shoot roots developed from the top node of the second plant during the same period. A similar result was obtained perhaps in a more striking manner by growing a third plant on all the sett roots developed from the bottom joint during the first two months and subsequently throwing the plant for a further period of two months on a couple of shoot roots developed from the top node. It is unfortunate that weights were not recorded at the time, but the pictures, drawn from photographs, are fairly conclusive. Over a dozen plants grown in the above manner gave similar results.

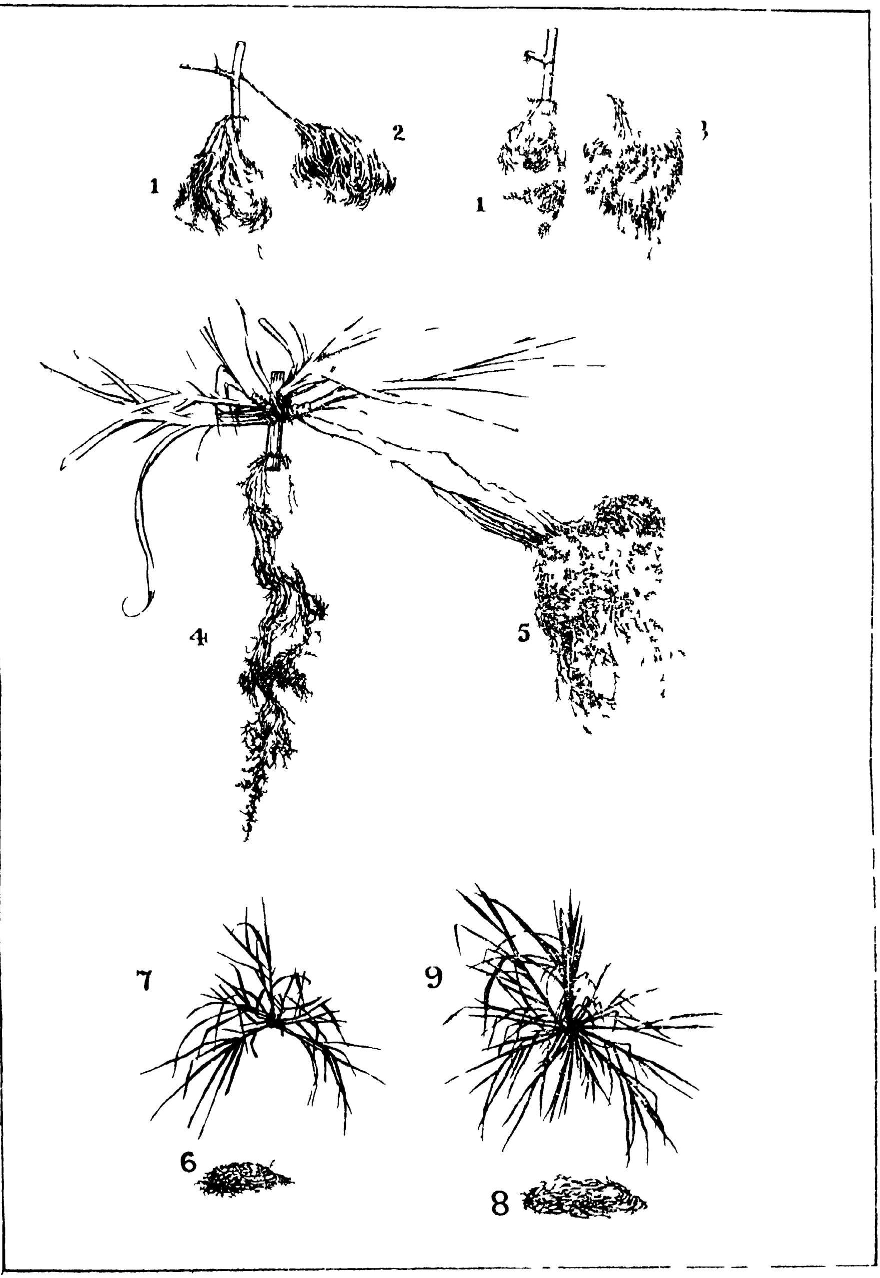
TABLE IV.

Relative densities of sett and shoot roots.

Name of variety	Age of plant at time of examination	Density of roots	
		Sett	Shoot
	Days		
Katha	58	0·20	0·13
	78	0·33	0·18
	104	0·33	0·19
Saretha	58	0·17	0·12
	81	0·25	0·16
	104	0·20	0·17
Hemja	60	0·16	0·15
	81	0·21	0·16
	105	0·33	0·17
247-B	62	0·17	0·13
	82	0·14	0·15
	109	0·22	0·17
E. K. 2	64	0·19	0·12
	83	0·22	0·16
	110	0·26	0·17

SETT VERSUS SHOOT ROOTS—DIFFERENCES IN GROWTH

(PLANT STUDIED Co 213)



1 Mass of sett roots from bottom node on which the plants (not seen in the picture) were originally started 2 Three months growth of sett roots from top node 3 Three months growth of shoot roots from top node 4 Two months growth from a large number of sett roots 5 Two months growth from a couple of shoot roots 6 Root growth during four months when the plant was made to depend on sett roots alone the shoot roots being removed as they were formed 7 Shoot of the above plant at four months 8 Root growth during four months, when the plant was allowed both sett and shoot roots 9 Shoot of the above at four months

Note—The plants 6 to 9 are not comparable with the others in the plate

(2) *Suggested reasons for the observed differences.*

While the shoot roots are markedly different from sett roots in both appearance and functions, a little consideration will show that they are after all similar to one another. A sett is really a piece of cane (as used in planting over the bulk of India), generally full grown, and carrying three buds. While examining the origin and development of shoot roots, it was observed that the shoot roots also had their origin from canes, though in a rather incipient state.

The sett roots are formed from fully formed canes, the canes themselves being in a dormant condition with dormant buds and root eyes. The shoot roots, on the other hand, take their origin from canes which are actually developing and consequently in an active state of growth. Secondly, the sett roots arise from canes which have no leaves attached to them. The canes producing shoot roots, on the other hand, are in organic connection with actively functioning and assimilating leaves; and it is therefore admissible to presume that these canes have circulating in them plant food in a form available for immediate use. The above differences are, in the opinion of the authors, adequate to explain the differences observed between the two kinds of roots. The fact that amongst the shoot roots themselves the late formed *i.e.*, those formed when the plant is in a more active and advanced state of growth are thicker than the earlier formed shoot roots lends some support to the above view.

(3) *Experimental evidence in support of (2) above.*

If, as has been assumed, the condition of the canes at the time of root formation is largely responsible for the differences noticed one should be able to obtain from the root eyes of a sett which, instead of being dormant, possesses organic connection with actively functioning leaves sett roots thicker and stronger than ordinary sett roots and rather comparable to shoot roots.

For this purpose a cane sett of seven joints was planted vertically in a pot, the bottom node alone being buried under the soil at the start of the experiment. All the buds in the sett were carefully removed except the top one, the root eyes being left intact in all the nodes. After a time and with the ordinary treatment, roots developed from the buried node much like ordinary sett roots (Pl. V, 1, (*b*)). With this development of sett roots, the top bud the only bud on the sett sprouted and after some time developed a shoot with active leaves. At this stage certain of the nodes above the bottom node (already in the soil) were treated for root development; and the roots thus developed (Pl. V, 1 (*a*)) were distinctly thicker than those of the bottom node and appeared to be more vigorous as well.

V. Certain interesting characteristics of sugarcane roots.

In the course of these investigations, sundry interesting characteristics of sugarcane roots were met with: and it is proposed to deal very briefly here with two of the more important of these.

(1) *Aerotropism.*

Roots of most cane varieties are positively aerotropic. There are, however, interesting differences between varieties in this respect, which are well brought out when canes are grown in water culture. The sett roots of Striped Cheribon, for instance, are more aerotropic than those of Katha—an Indian cane not quite intolerant to water-logging (Pl. VIII, Figs. 1 and 2). In both Hemja (an Indian cane commonly grown in the Gangetic plain) and in Badila, the branches arising from the first formed sett roots are aerotropic (Pl. VIII, Figs. 3 and 4). Fig. 5 in the same Plate shows the roots of another tropical cane -Red Sport of Striped Mauritius—growing towards the surface of the soil in the plot.

The grass *Sacch. spontaneum* is able to grow under water-logged conditions and seedlings derived from it have shown similar resistance to water-logging. The authors have derived useful indications in this matter from plants grown in water culture. Compared with Indian canes, the tropical kinds are more difficult to grow in water culture, some of them often dying after four to six weeks. Certain seedlings derived from *Sacch. spontaneum* have been known to grow in water culture solutions and with but little attention for over eight months.

(2) *Adaptations for rooting efficiency.*

Pl. IX, Figs. 1 and 2 show a rather interesting adaptation by which the roots of a shoot, growing well above the soil, manage to reach to it. The roots first produced from the above-ground shoot in Fig. 1 became dwarfed, apparently on account of their inability to function properly. Further roots were successively developed from the shoot and met with a similar fate, till the mass of roots almost reached to the soil and formed in effect a kind of bridge between the shoot and the soil. The latest roots to be developed reached the soil over this mass of roots (Pl. IX, Fig. 2). Once the soil was reached, the roots grew in the normal manner.

Yet another adaptation conducive to rooting efficiency is the depressed habit of the first formed shoots. Such a habit almost buries the shoot— and hence the incipient cane in the shoot into the soil, thus contributing to an early development of roots and tillers from the first formed shoots. Pl. IX, Fig. 3 shows three such depressed shoots in darker lines.

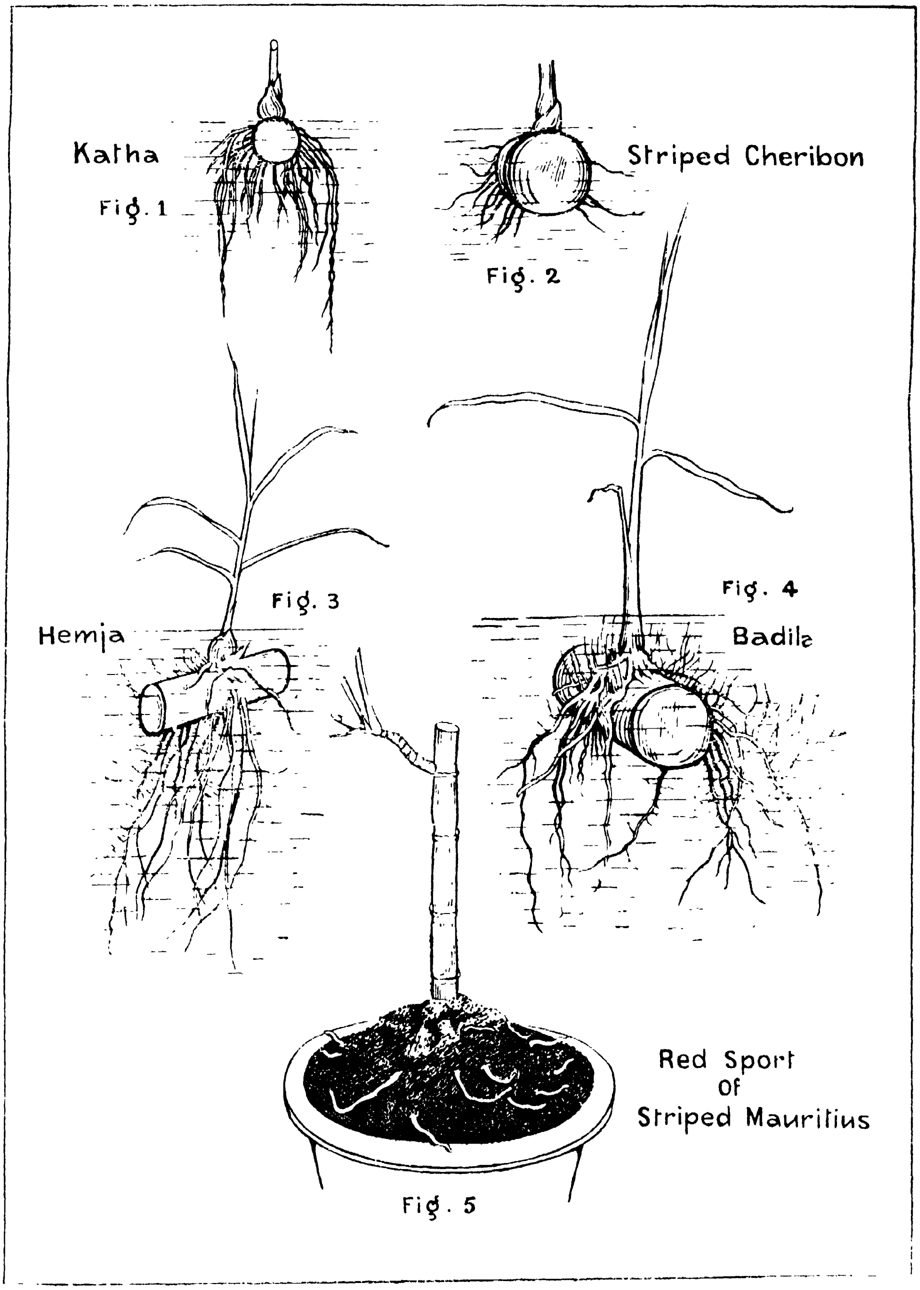
VI. Summary and Conclusion.

During the germination or sprouting of sugarcane setts, the development of roots from the dormant root eyes is one of the first activities.

The roots thus developed from setts have been styled "*sett*" roots in contrast to "*shoot*" roots which are developed later from the shoots.

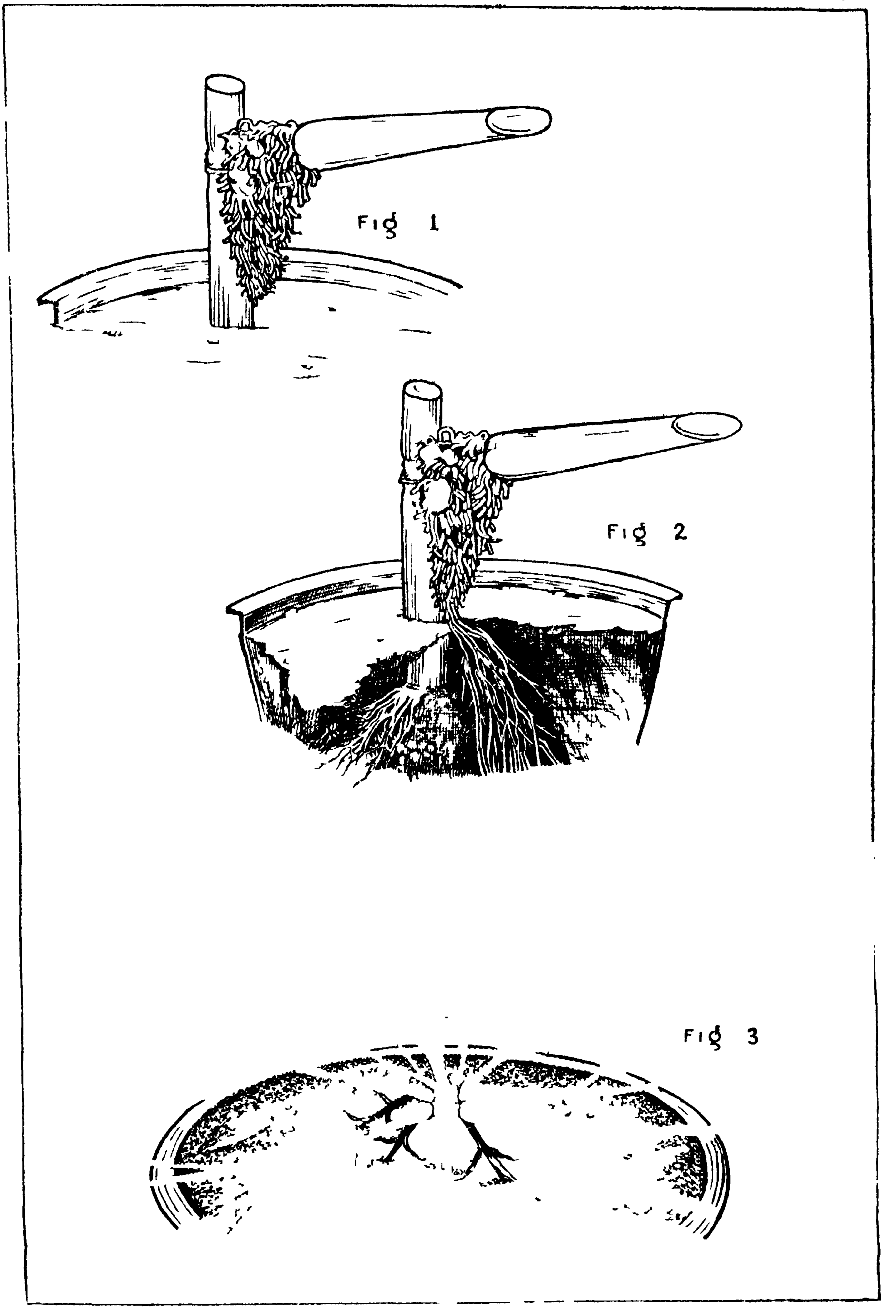
There is no correlation between sett root production and the sprouting of buds. For the full development of the bud into a shoot, however, sett roots are *essential.*

Aerotropism in Sugarcane roots.



1 to 4 were grown in water culture.
Sugarcane varieties differ in the relative resistance of their roots to water-logging. Before introducing a new cane into a locality liable to water-logging, its root behaviour to such conditions should be studied to avoid disappointment. Quite recently the senior author recommended a cane to such conditions on the strength of its root behaviour in water culture, and the cane has since proved a success.

Adaptations for rooting efficiency



Figs. 1 and 2 show how the dwarf aerial roots from an above-ground shoot form a kind of bridge for the latter developed roots to reach to the soil

Fig 3 shows how the depressed habit of early shoots presses the shoots (darker lines) into the soil This helps tillering varieties which have a depressed habit in the early stages, not only keep down weeds by covering the ground, but sometimes prove good tillerers as well

Interesting differences exist between cane varieties in the number, length and functioning period of sett roots produced during germination. In certain canes only a portion of the root eyes produce roots, the rest remaining dormant till a need arises. This is considered to be a definite and valuable provision against possible adverse conditions during the later stages of growth.

Irrigation with saline water is harmful to sett root development and should be avoided.

In most canes, sett roots die after a time and, subsequent to this, the plants are dependent on "shoot" roots developed later from the young growing shoots.

The rate of growth of the above ground portion of the cane plant is positively correlated with the growth vigour of shoot roots and the study of these roots thus becomes a matter of great importance to the cane grower.

During the adult stage of the cane plant there is almost a continuous development of new roots, resulting in a constantly changing root system which readily adjusts itself to changes in the environment.

If the cane is prevented from thus developing new roots, it gradually loses vigour and dies.

It is desirable to work out for each variety its typical root system and find out exactly where (in the soil) and when the series of successive new roots are developed. Such knowledge would materially help in indicating beforehand the conditions under which the variety is likely to do its best. It would further be of great use in guiding manurial and cultural operations with the maximum advantage to the growing crop.

Sett roots differ from *shoot* roots in certain respects, the generally greater growth vigour of the latter being the most important difference.

The observed differences between the two classes of roots arise, it is suggested, from differences in the condition of the canes giving rise to each class.

Certain interesting adaptations in sugarcane roots, such as aerotropic curvatures and arrangements for ensuring an efficient rooting, are briefly described.

The above ground portions of plants have been receiving attention at the hands of botanists and crop specialists for some considerable time. It is only in recent years that some attention by no means adequate has been directed to the study of the chief underground portions of plants, the roots. To the agriculturist the study of roots is of paramount importance, as it is only through them and with their help that it is, generally, possible to influence the growth and production of the above, ground portions, which supply practically the whole of the food required by man and beast. The data presented in this paper have indicated certain of the directions in which knowledge of roots and root systems would be of direct benefit to the cane grower. Better and more work is needed to fully understand and influence to the advantage of mankind such a valuable food crop as the subject of this paper, the *sugarcane*.

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